THE SURGICAL TREATMENT OF SCOLIOSIS

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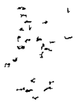
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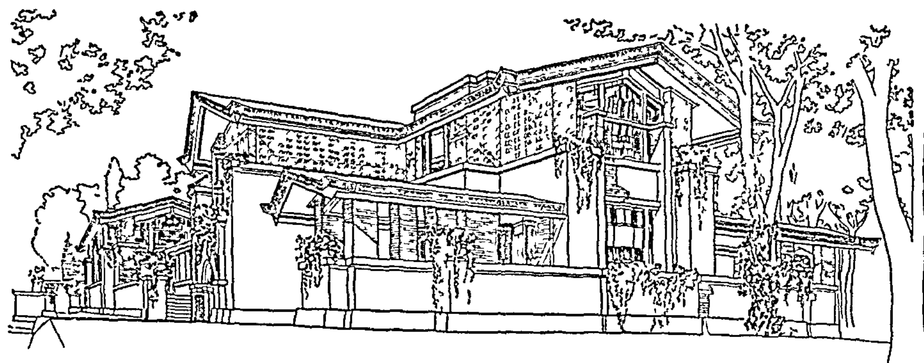
Appendix

ANESTHESIA IN SCOLIOSIS

By

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This woık is dedicated

to

DR. R. PLATO SCHWARTZ

whose foresight created the

experience which forms the

basis of this monograph.

Preface

TWENTY YEARS AGO, Dr. R. Plato Schwartz suggested the adoption of a planned program of treatment for scoliosis at the University of Rochester Medical Center and assigned the task of organizing such a program to the author. This opportunity provided a basis for an organized attack on the scoliotic problem at this clinic. A program was worked out and a plan embarked upon which has borne fruit beyond expectations. Such an experience, pursued throughout the years, may contain elements of value to those who are likewise confronted with similar problems. Few changes in the basic approach were found necessary even though the number and types of scolioses increased.

Soon after the author manifested a special interest in scoliosis, his orthopedic colleagues referred scoliotic children to him for treatment. As a result a significant experience was acquired. This planned program of approach and the concentration of effort at one center resulted in the more effective handling of the scoliotic problem in this area with greater benefits to the afflicted children under treatment.

The technique of correction and the maintenance by spinal fusion are not original with the author, but certain aspects may be regarded as the result of an expanding experience. This monograph deals with this method of treatment and the results achieved.

Acknowledgments

It is with pleasure that I acknowledge my indebtedness to the many individuals who shared in one way or another in bringing this monograph to completion.

The treatment of scoliosis in the turnbuckle plaster cast requires meticulous attention to detail and many hours of arduous toil during the process of correction. Without the loyal and constant efforts of the succession of orthopedic House Officers at the University of Rochester Medical Center, this would not have been possible.

In the Appendix, Dr. D. Vernon Thomas, Head of the Division of Anesthesia, discusses related problems peculiar to the scoliotic patient. His able and cooperative staff has provided the skillful anesthesia so important in the surgical treatment of scoliosis.

Funds available through the efforts of Dr. Donald G. Anderson, Dean of the University of Rochester Medical Center, and Dr. W. J. Merle Scott, Chairman of the Department of Surgery, made possible completion of the follow-up studies and determination of the end results of treatment reported in this monograph. Dr. W. W. Howe, Jr. was very helpful in his critical review of the manuscript during its preparation as were the editorial suggestions made by Mrs. Florence Cooksley and Miss Cecilia Connorton.

The excellence of the roentgenograms appearing in the illustrations is testimony to the unusual cooperation of the Department of Radiology through the years in coping with the many technical problems that arose in providing roentgenograms of good quality. The illustrations were made by Mr. John Gaughan and his staff in the Department of Medical Photography. Mr. Gaughan spared no efforts and his part in this project far exceeded the ordinary responsibilities of his position. The drawings and charts were executed by Mr. Grant Lashbrook of the Department of Medical Illustration.

Mrs. Clara Taylor, Miss Janet Champney, and Miss Elizabeth McIntee were most cooperative in the demands on their time and effort in typing and retyping manuscript and tables.

Finally, but of equal importance, I owe to my wife, Mildred, an incalculable debt, for without her infinite patience and constant encouragement this book might never have been completed.

J. A. G.

Contents

THE SURGICAL TREATMENT OF SCOLIOSIS

CHAPTER I

General Considerations

THE HUMAN SPINE is held erect by active muscular support and a sense of balance. There are, normally, physiological curves in the sagittal plane, but the spine is straight when viewed in the frontal plane.[17] Under certain circumstances in childhood, at times from a known cause (paralytic), and at other times from an unknown cause (idiopathic), a lateral angulation develops in the vertebral column. The sense of balance and the functioning of the trunk muscles together strive to keep the head and shoulders centered over the pelvis in both the frontal and sagittal planes. This results in the development of counter curves in the spine above and below the initial angulatory deviation. Because the spine is an asymmetrical, flexible rod, deformities can occur in two planes; lateral angulation in the frontal plane and rotational deviation in the sagittal plane. The rotation of thoracic vertebral bodies is reflected in progressive morphologic changes in the rib cage. Associated pelvic deformity may also occur. These changes comprise the scoliotic deformity.

THE PROBLEM

Most physicians believe that the progress of the deformity in any particular case of idiopathic scoliosis depends more upon the curve pattern and the age at onset than it does on conservative therapeutic measures employed during the active evolution of the disorder. On the other hand, in paralytic scoliosis conservative measures, such as exercises, recumbency and external support, play an important part in halting the development and progress of the curve. Some cases of idiopathic scoliosis, and a higher percentage of the paralytic curvatures, present problems that require surgical treatment for effective solution.

PROGNOSIS IN IDIOPATHIC SCOLIOSIS

Basic to proper treatment of structural scoliosis is a knowledge of the natural history of the disease. Over a quarter of a century ago, Risser and Ferguson noted the relationship between the spinal growth and the increase of deformity in idiopathic scoliosis, and its cessation when the bony structures mature. This usually occurs at the age of

sixteen in boys and fifteen in girls. A recent significant contribution to the understanding of the disease process was made in 1950 by Ponseti and Friedman who studied the cases treated without operation in Steindler's clinic. They arrived at a classification of idiopathic scoliosis based upon curve patterns which provides a simple and practical basis for prognosis of a particular curve·

1. Main Lumbar Curve
2. Thoracolumbar Curve
3. Main Thoracic Curve
4. Combined Thoracic and Lumbar Curves
5. Cervicothoracic Curve

They pointed out that age is a factor in prognosis The thoracic curve and in particular this curve with onset prior to the age of ten years carries a poor prognosis and usually results in a severe deformity.

James, in 1954, further defined the prognostic significance of curve patterns in relation to age of onset. James referred to three peak periods in the onset of idiopathic scoliosis, namely: under three years of age, between five and eight years, and over ten years of age. He subdivided the thoracic curve pattern into three groups corresponding with age of onset, designating these as *infantile* (onset under three years of age), *juvenile,* (onset between five and eight years of age), and *adolescent* (onset over ten years of age.) Relating prognosis in these groups to the development of a 70-degree, or greater, curve, he found that the deformity exceeded 70 degrees in all the infantile cases and in 87 per cent of the juvenile cases. In 59 per cent of the adolescent cases the curvature increased beyond 70 degrees.

James[14] reported nine cases, and Scott and Morgan seven cases of infantile idiopathic thoracic scoliosis which disappeared spontaneously. These authors point out that the curve is usually mild in idiopathic infantile thoracic scoliosis. It measured less than 20 degrees in all of James' patients but exceeded 20 degrees in two of Scott and Morgan's cases. James noted that the curve disappeared under two years of age. Scott and Morgan referred to this infrequent curve pattern as *resolving infantile idiopathic scoliosis,* as contrasted with the *progressive infantile idiopathic scoliosis*. The resolving type requires no treatment.

In making a *prognosis* in a particular case of idiopathic scoliosis, prior to the chronological age of cessation of rapid spinal growth, it would appear that several observations should be taken into consideration — these are listed in the order of their relative importance. (1) *the curve pattern,* (2) *the age of onset,* (3) *the skeletal age;* (4) *the status of ossification pattern of the iliac apophysis;* (5) *the stage of development of the physical characteristics of puberty.*

Clarification of some of the controversial issues concerning conservative management and operative treatment of scoliosis may occur in the

near future. This will be true particularly if the effectiveness of treatment is evaluated in the light of recent knowledge of the natural course of the disease and the possible prognosis.

RESULTS TO BE ACHIEVED

The object of treatment in *idiopathic scoliosis* is to obtain some measure of correction, and to prevent further increase of the deformity in the growing child. A degree of correction of the curvature that will result in good body balance is sought for in the adolescent patient who has completed spinal growth. Correction of a severe deformity, or prevention of the progress of a moderate to severe deformity, secondarily promotes better function.

The goal of treatment in *paralytic scoliosis* is the correction of the existing deformity, the prevention of further deformation, and the stabilizing of a spine that has lost part of its normal muscular support. Reduction of fatigue and increased tolerance for action are frequent by-products achieved in these patients.

METHOD OF TREATMENT

Initial Management

The scoliotic child is placed on a conservative routine and followed until such time as a specific indication for surgical treatment arises.

In idiopathic scoliosis, treatment requires regular clinical and roentgenographic examinations to observe and record the progress of the curvature during growth. General exercises are prescribed to attain as good posture as possible, as well as limbering exercises to retain a reasonable mobility of the spine. If there is a significant increase in the curvature during the growth period, or if the severity of the deformity warrants, treatment by correction of the curvature and spinal fusion is then considered. This program is based upon the works of Hibbs, Risser, Ferguson, Smith and Butte, and later modifications as influenced by the work of Cobb.

A paralytic scoliosis is treated more aggressively than an idiopathic curvature during the period of evolution of the deformity. Initially — particularly in the younger child — prolonged recumbency is advocated. Stretching exercises are instituted to maintain good spinal mobility, and to prevent or minimize contractures. Active exercises are prescribed to strengthen the weak trunk muscles. Bent plaster shells are used intermittently to counteract the deforming attitudes. The vertebral column is usually supported with a removable straight or bent plaster jacket for walking.

In progressive curves in younger children, a Milwaukee brace is used at night, after school and week ends. Ilio-tibial band contractures, causing pelvic obliquity, are corrected surgically.[12a]

Consideration is also given to gait patterns in patients with involvement of the lower extremities. The continuous use of crutches and a swing-through gait is encouraged, when feasible, to prevent unusual and excessive strains on the trunk.

Surgical Treatment

After analysis of the deformity and determination of the desired degree of correction to be accomplished the curvature is corrected in a turnbuckle plaster cast. This correction is maintained by fusing a predetermined area of the vertebral column.

CHAPTER II

Review of Procedures in Use

CONSERVATIVE TREATMENT

CONTROVERSY STILL EXISTS regarding the effectiveness of conservative measures in the treatment of scoliosis. In 1930 Ferguson, representing the New York Orthopedic Hospital Group at the time stated, "the only treatment that is effective in stopping the progress of a curve is operative fusion. In other words, if a scoliotic case needs any treatment other than mere postural exercises, it needs operative treatment. We have no case in which under any other method of treatment we have been able to prove arrest of progress or even limitation of progress. Likewise, we have no cases in which we have secured partial or complete correction in which the correction was maintained except by operation." The opinion of Ferguson and his coworkers has not changed materially since 1930.

Von Lackum in 1946 stated that "the 'corrective exercises' recommended in the conservative management of the scoliotic patient is expected to accomplish an improvement in posture, to maintain maximum flexibility of the spine, to facilitate follow-up of the patient and occasionally to arrest and improve the deformity somewhat." He stated that 5 to 8 per cent of the patients observed require surgical intervention. Cobb believed that "careful observation and adequate follow-up are the most important conservative things we can do in a case of scoliosis." Less than 5 per cent of Cobb's cases came to operation.

In 1941, an "End Result Study" sponsored by the American Orthopedic Association showed in part that in 60 per cent of those patients treated by exercises the deformities increased and in 40 per cent they remained unchanged. Also, correction without fusion in the majority of instances resulted in complete loss of correction after the support was discontinued. The American Academy of Orthopaedic Surgeons' Committee to Study Scoliosis reported in 1949 that the members could not agree on the value of "corrective support" and exercises in the treatment of non-paralytic scoliosis.

Steindler[20] approached the treatment of the scoliotic deformity by attempting to create compensatory counter curves, rather than by correcting the primary curve. After twelve years of experience, he reported

in 1939 that 40 per cent of the patients treated by his method were able to maintain the compensated position. The same author in 1941 stated that the vertebral column need not be fused if compensation could be accomplished without forcible cast correction, and if muscle development were adequate. He stated, however, that if compensation must be forced by a cast, then fusion will become necessary to maintain the correction. In 1950, Steindler further defined the limitations of this form of conservative management by stating that the primary thoracic, the cervicothoracic, and the lumbar scoliosis when it includes the pelvis, are not controlled by conservative treatment.

James, in 1954, reported an "Evaluation of cases of scoliosis observed and treated at the Royal National Orthopaedic Hospital." When prognosis was related to the curve pattern and age of onset, he found no evidence that any form of conservative treatment influenced the progress of the curve. In the same year, Blount, in a paper given at the Sixth Congress of the International Society of Orthopaedic Surgery and Traumatology, stated, "We must abandon the defeatist attitude that conservative treatment is futile. Some curves may be improved and the ultimate progression retarded without operation." Blount did not, however, define or indicate which types of curves so responded to conservative treatment.

Although Cobb[4] subscribed to the relation of spinal growth and progression of deformity in idiopathic scoliosis, he further believed that "since idiopathic scoliosis stops spontaneously at an uncertain time (at or before age seventeen usually), it is difficult to prove that any specific treatment stops the progress of a certain curve, it may have stopped spontaneously at that time." His experience indicated that the curvature continued to progress throughout the period of spinal growth in some patients but ceased prior to maturity in others. Risser[22] correlated the completion of vertebral growth and the cessation of progression of the deformity in idiopathic scoliosis with the completion of ossification of the iliac apophysis.

Calvo found skeletal age the most reliable indication of the cessation of spinal growth in females. He states: "For practical purposes growth activity ceases in the spine at a skeletal age of sixteen years . . . Scoliotic curves do not increase after the skeletal age of fifteen years, and in 35 per cent of the cases this skeletal age appears a year earlier than the completion of the iliac apophyses."

Use of Appliances

Three basic forces are used to exert a corrective influence on a scoliotic deformity, namely, lateral bending, distraction, and shifting. Several types of appliances, incorporating one or more of these passive correcting forces, are currently in use for preoperative correction of the curva-

ture. Among these, the Risser turnbuckle plaster cast[12] is the device most frequently used, because it takes advantage of both lateral bending and distracting forces to bring about a desired correction. It has proven effective in the hands of many surgeons. A hanging fish-net method reported by LeMesurier also takes advantage of both the lateral bending and distracting forces.

The distracting force alone has been used in several other types of appliances. Donaldson and Engh incorporated such an element in a two-section plaster cast that included only the pelvis and the thorax. This cannot be effective in the more severe and rigid curvatures. The Milwaukee brace uses the distraction principle by incorporating a head-piece in the apparatus. The two-section plaster jacket used by Stagnara has a snug well-molded pelvic girdle and a well-molded head-piece attached to the thoracic section. Correction is accomplished entirely by turnbuckle distraction. James[15] adopted Stagnara's distraction jacket for the correction of high thoracic curves and the combined thoracic and lumbar curves, because he has found these patterns unsuitable for turnbuckle jacket correction. However, severe and troublesome chin pressure is a serious problem in using the Stagnara jacket. James considers the head-piece in the turnbuckle cast unnecessary. In my own opinion the combined thoracic and lumbar curves may be satisfactorily treated in a turnbuckle cast if the objective of treatment is correction and fusion of the thoracic curve alone.

von Lackum uses the *transection* plaster cast in selected cases to correct the deformity by shifting of the thorax on the pelvis. Risser[23] has recently introduced the use of a "localizer" cast, which substitutes direct pressure over the apex of the curve for lateral bending in the presence of a distracting force.

TREATMENT BY FUSION

Most orthopedists agree that vertebral fusion is necessary to maintain a corrected scoliotic curve. A report published by the Research Committee of the American Orthopaedic Association in 1941 on "End Results in the Treatment of Idiopathic Scoliosis" showed that in the majority of instances correction of scoliosis without fusion resulted in complete loss of correction after use of the support was discontinued. This Committee also found that the *turnbuckle plaster jacket and vertebral fusion have produced better results than any other type of treatment*. Despite these findings, there still remains considerable confusion and a wide divergence of opinion among orthopedic surgeons on many questions regarding treatment of scoliosis.

Another Committee appointed by the American Academy of Orthopaedic Surgeons to study scoliosis reported its findings in 1949. The members emphasized the need for clarification and more knowledge of

methods of treatment in scoliosis. Controversial points that could not be agreed upon by the committee members included the following: Selection of patients for vertebral fusion; most favorable age for fusion; effect of early fusion on the growth of the vertebral column; the area that should be fused; the desirable degree of correction of a curve before fusion is performed, and the postoperative effect on unfused curves.

One of these points, the effect of early fusion upon the growth of the spine, was clarified by Ponseti and Friedman in 1950. Their report from Steindler's Clinic on 117 cases of scoliosis treated by vertebral fusion stated that "the growth of the fused segment of the spine in young patients was absent or minimal except when pseudarthrosis occurred"

Risser[22] continues to do fusions early, even in patients as young as seven years of age. James advises early operation but not under ten years of age in infantile idiopathic scoliosis. Steindler[20] believes that one should, if possible, wait until skeletal development is more nearly complete, and suggests the age of fourteen years. He also recommends that up to that time scoliosis should be treated conservatively in order to provide time for as complete compensation as possible. Cobb advocates carrying the patient to as near completion of spinal growth as possible, preferably at least to age thirteen years and six months. Exceptions are patients with kyphotic deformities, who may be considered earlier for fusion.

The indications for fusion in scoliosis as outlined by Ferguson in 1930 are: (1) if the curve is unsightly and correctible, (2) if it is physiologically deleterious and correctible; (3) if it is progressing.

I believe that these fundamental indications still hold. The newer knowledge of the progressive scoliotic process allows us to anticipate the curve with a probable bad prognosis at an early age. This permits consideration of more aggressive palliative corrective measures during the evolution of the curve (Chapter VII) and in selected cases, fusion at an earlier date.

CHAPTER III

Preoperative Analysis and Correction

THE METHOD TO BE DESCRIBED has been used in the treatment of sixty-five patients with structural scoliosis.

SOURCE OF MATERIAL

In this series there were thirty-seven cases of idiopathic scoliosis, twenty-three cases of curvatures due to paralytic poliomyelitis, four cases of congenital bony anomalies, and one case associated with neurofibromatosis.

CLASSIFICATION OF SCOLIOSIS

A. Idiopathic Scoliosis — 37 cases.
  1. Main lumbar curve — 1 case.
  2. Thoracolumbar curve — 6 cases.
  3. Main thoracic curve — 25 cases.
    a. Infantile — no cases.
    b. Juvenile — 12 cases.
    c. Adolescent — 13 cases.
  4. Combined thoracic and lumbar curve — 5 cases.
  5. Cervicothoracic curve — no cases.
B. Paralytic Scoliosis — 23 cases.
C. Congenital Scoliosis — 4 cases.
D. Miscellaneous — 1 case.

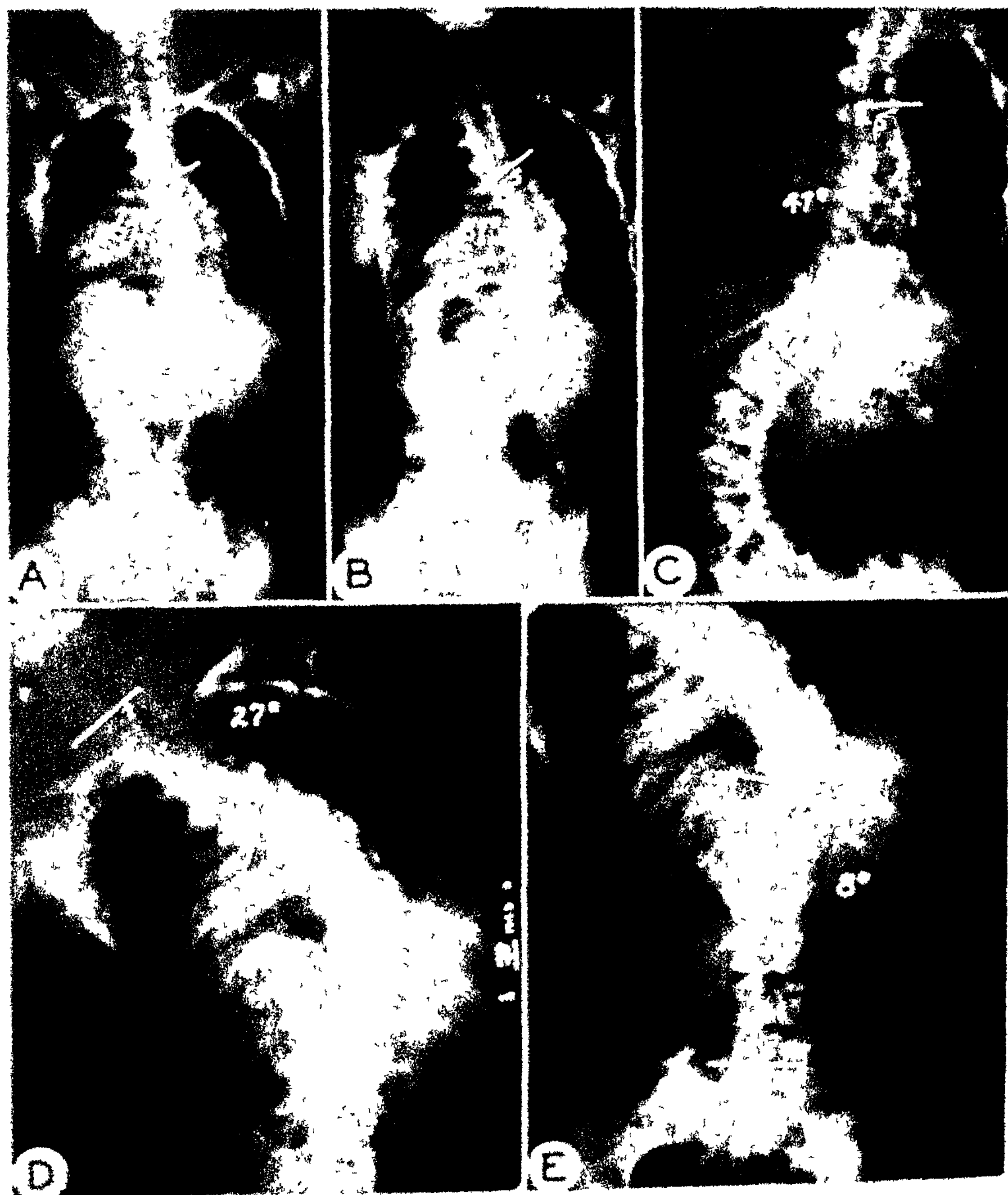
I have followed fifty-two of these patients for two years or more and two others for eighteen months. A critical and detailed analysis of the results of surgical treatment on these patients is the material on which this book is based.

ANALYSIS OF THE SCOLIOTIC DEFORMITY

Roentgenographic Survey

A complete roentgenographic survey of the entire spine is made (Fig. 1), including anteroposterior roentgenograms made with the patient supine, standing, and bending to the right and the left. In the older children, 14 by 36-inch roentgenograms are used for the supine and standing exposures to allow inclusion of the entire spine (Fig. 1 A, B).

Comparison of the findings in the recumbent and upright position gives an index of the relative mobility of all of the curves. The roentgenogram made in the erect position is used for measurement of the curves preoperatively and for comparison with and evaluation of the final result of treatment, because we are primarily interested in the status of



[illegible] ANTEROPOSTERIOR ROENTGENOGRAMS OF THE SPINE

[illegible]

[illegible]

[illegible]

[illegible]

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the spine in the upright posture. The lateral bending roentgenograms (Fig. 1 C, D, E) allow determination of the degree of fixed angular deformity in the compensatory counter curves as well as an estimation of the relative correctibility of the primary curve.

The Primary Curve

The criteria for identifying the primary curve are as follows:

1. It is the middle curve in a three-curve pattern (main thoracic type curve). In a four-curve pattern, as provided by combined thoracic and lumbar curves, there are two primary or major structural curves.
2. It is less mobile than the compensatory curves.
3. In decompensation of the trunk, the list is to the side of the primary curve.

Extent of the Curve

The end vertebrae of the primary curve are identified by the following observations, as illustrated in Fig. 2.

1. *The shape of the disc space*: The intervertebral disc space is narrower on the concave side and wider on the convex side of the curve. At the top and bottom of the curve, the intervertebral space either is of uniform width or is wider on the concave side of the curve.
2. *The degree of rotation of the vertebral body*: This is determined by the degree of deviation of the tip of the spinous process away from the center of the vertebral body. The bodies of the top and bottom vertebrae should be rotated the least into the curve, as indicated by the location of the spinous process toward the mid-point of the vertebral body.
3. *The tilt of the vertebral body*: The end vertebrae in the curve are the last vertebrae whose superior and inferior surfaces tilt toward the concavity of the curve.

   Occasionally these three characteristics do not agree on a single end vertebra. In such cases, the vertebra more distal from the center is selected.

Degree of Angulation

Perpendiculars to the superior surface of the top vertebra and to the inferior surface of the bottom vertebra are drawn on the roentgenogram and the angle formed by these two intersecting lines is the angle of the curve (Fig. 3).

Allowable Correction

Two observations determine the allowable correction. The first is the degree of fixed deformity in the compensatory counter curves. This is determined from roentgenograms made with the patient bending in

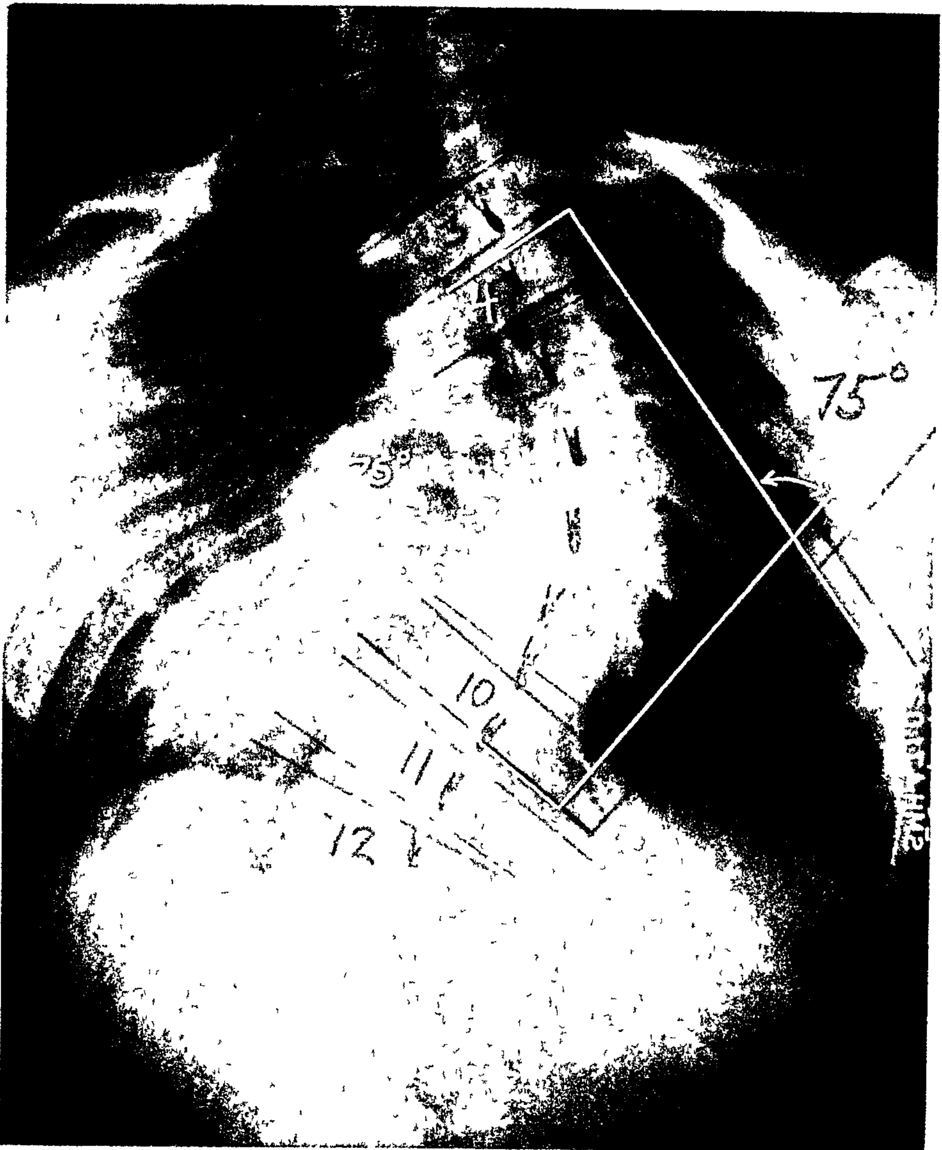


Fig. 2 Determination of the Extent of a Curve The fourth thoracic vertebra is identified as the top vertebra and the tenth thoracic vertebra as the bottom vertebra in this primary right thoracic curve.

the direction of the concavity of the primary curve. The degree of fixed angulation in each of the compensatory counter curves is then measured (Fig. 1 D, E). In the earlier cases the pelvic tilt roentgenogram as described by Ferguson was employed. In recent years we have used the lateral bend test described by Cobb,[4] because it enables us to measure the degree of fixed angulation in the upper thoracic curve as well as in the lumbar curve.

The second criterion in determining allowable correction is the alignment of the end vertebrae in the fusion area on the "correction roentgenogram" to each other and to the lateral bend or pelvic tilt roentgenogram. There are three observations that may be made in relation to this characteristic: First, the inferior surface of the bottom vertebra and the superior surface of the top vertebra in the fusion area may be parallel



FIG 3 THE METHOD USED FOR MEASUREMENT OF THE CURVES (*after J R Cobb*)

to each other (Fig. 4 D), or they may tilt toward the concavity of the primary curve (Fig. 5 D). However, these surfaces must not be permitted to tilt away from the concavity of the primary curve. The latter circumstance indicates an over-correction. Secondly, a perpendicular erected from the inferior surface of the bottom vertebra may pass up through the top vertebra (Fig. 4 D) or along its convex side (Fig. 5 D) but it may not pass along its concave side The latter circumstance is also indicative of over-correction. Finally the "correction roentgenogram," with the fusion area delineated, is superimposed on the pelvic tilt or lateral bend roentgenogram (Figs. 4 F and 5 E). This should show good general alignment of the spine.

As a basic principle, *the angular deformity of the primary curve should not be corrected beyond the sum of the fixed angulation of the*

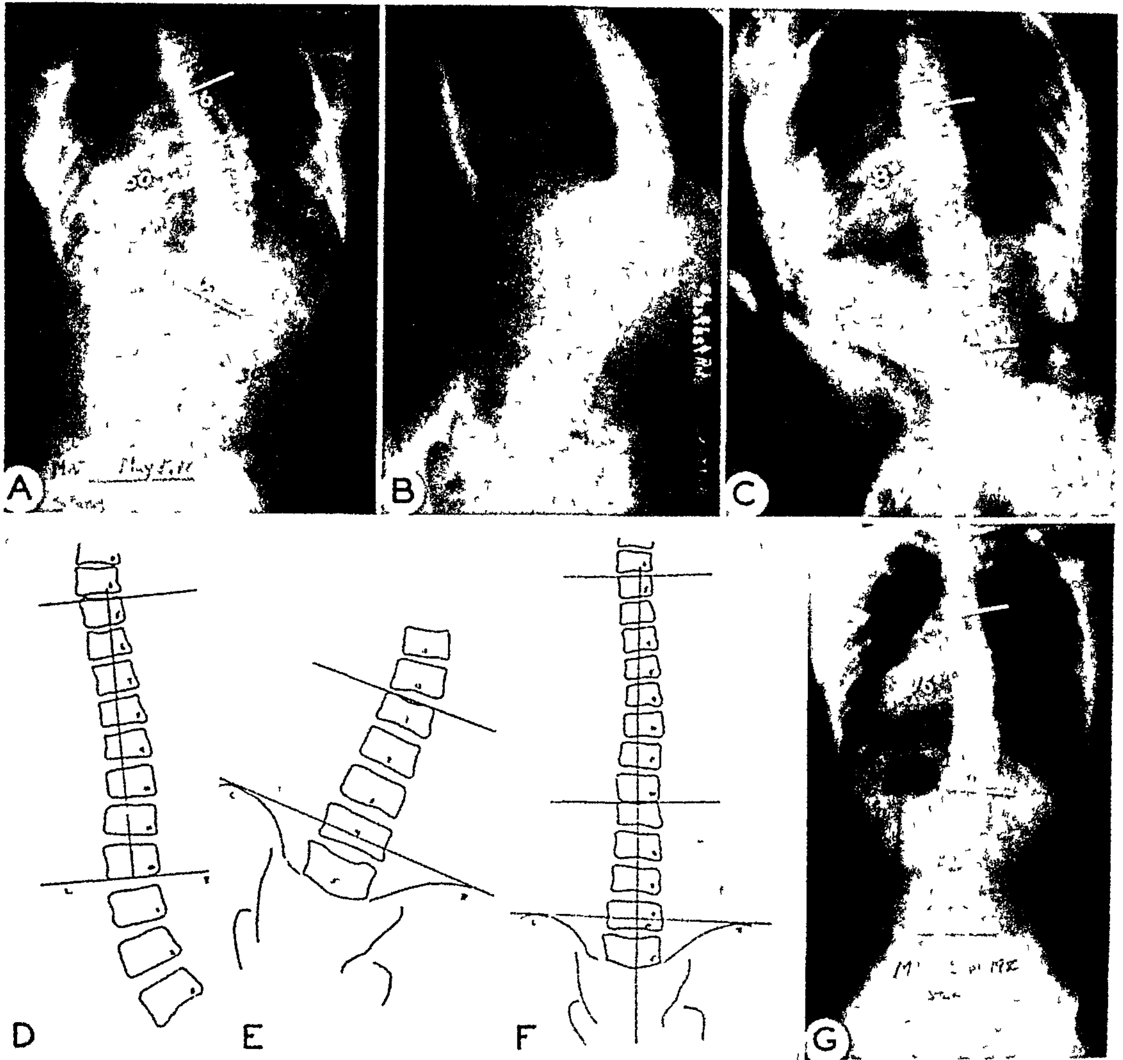


FIG 4 ILLUSTRATING THE PRINCIPLE OF FUSION BETWEEN PARALLEL VERTEBRAE

A—Idiopathic thoracic curve Roentgenogram made in erect position
B—Left pelvic tilt roentgenogram shows complete correction of the left lumbar curve.
C—Preoperative correction in turnbuckle cast as seen on the "spine marker" roentgenogram
D—Tracing of Figure 4 C.
E—Tracing of Figure 4 B.
F—Composite of Figures 4 D and E
G—Roentgenogram made in erect position ten years postoperative. (From *Medical Clinics of North America*.[9] Courtesy, W. B. Saunders Co, Philadelphia, Pennsylvania)

compensatory counter curves, because this may lead to the inability of the spine to compensate and may result in an unbalanced trunk.

THE TURNBUCKLE CAST

The turnbuckle plaster cast as devised by Risser and modified by Cobb has been used. Experience in its use has emphasized the importance of careful attention to details in applying the cast. Through

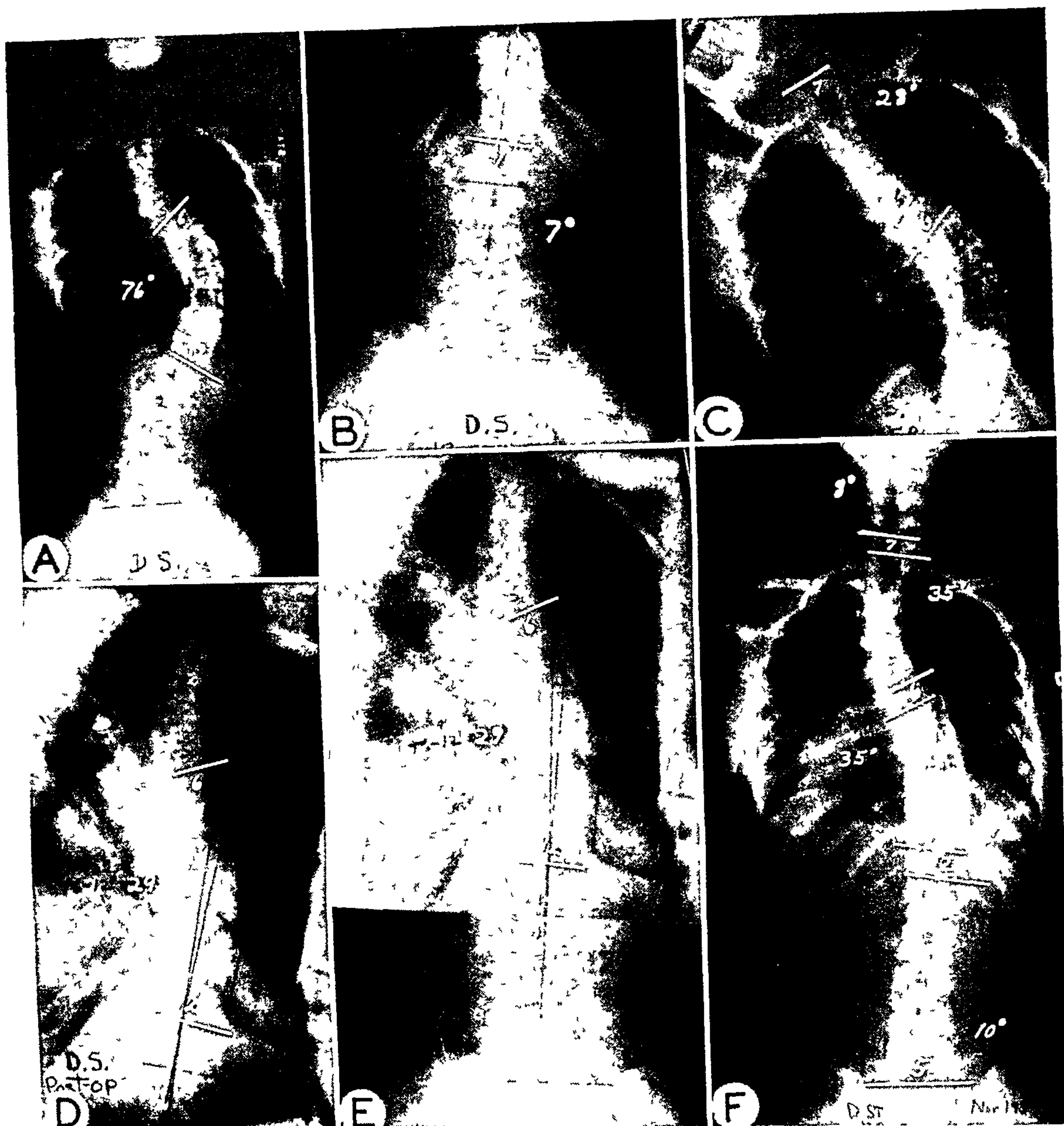


Fig 5 Principles in Preoperative Correction of the Curvature

A—Idiopathic right thoracic curve.

B—Left bend for lumbar curve shows 7-degree fixed angulation

C—Left bend for upper thoracic curve shows 28-degree fixed angulation

D—Preoperative correction in turnbuckle cast shows 29-degree residual right thoracic curve — theoretically 6 degrees over-correction but from a practical standpoint within the limits of measurement error

E—Correction roentgenogram superimposed on left bend roentgenogram showing good general alignment. The bottom vertebra (L1) in the proposed fusion area is superimposed on the adjacent second lumbar vertebra in the left bend roentgenogram

F—Three years' postoperative (erect position) curve measurements show good balance between angular deformities to the right (T6-12=35°, Cl-7=8°) and to the left (C7-T6=35°, T12-S1=10°)

the years, minor modifications have been made, resulting in more effective use of the cast and more comfort to the patient. A description of the technique for applying the cast follows.

Technique of Application

A modified Goldthwaite frame (Fig. 6 B) which was fabricated in our hospital machine-shop is used on a fracture table (Fig. 6 C). The patient is placed supine on the frame which is bent toward the side of the concavity of the primary curve. This partially straightens the compensatory curves and allows maximum correction of the primary curve with minimum increase in the compensatory counter curves. Therefore, less angulation occurs in the compensatory counter curves during the long period of immobilization in the turnbuckle plaster cast. The head is also flexed toward the same side to avoid undue tension on the neck during correction.

Stockinet is first applied covering the head, trunk and both thighs. Pieces of felt are made ready (Fig. 6 A) before the patient is positioned and are applied over the stockinet. A long piece of felt (*i*) is placed over the irons. A large rectangular piece (*d*) is applied to the back of the head, tucked into the hollow of the neck and down over the back of the shoulders, and held in place over the Goldthwaite irons. Another rectangular piece (*b*) is thoroughly soaked in warm water and wrung out, and a pocket is fashioned for the chin. The wet felt allows accurate molding under the chin and over the anterior neck. A 2 by 2 by ½-inch piece of felt, with an attached length of gauze bandage (*f*) which allows easy withdrawal after the cast is complete, is tucked over the larynx. The 6-inch strips (*c*) are next applied around the trunk. Strips of felt are used because they allow smoother application and spread easily as correction progresses. A pad of three thicknesses of felt (*e*) is placed over the thorax on the convex side of the curve extending up to the axilla. Removal of the felt pieces as wedging of the cast progresses makes room for the shifting thorax and avoids excessive pressure over the rib cage. A piece with a pre-formed pocket (*h*), or a soft sponge rubber pad is added over the crest of the posterior rib rotational prominence if the deformity is severe. Extra pieces are also placed over the iliac crests of very thin patients. The thighs, which are supported in slings in a moderately flexed and abducted position, are adequately padded with sheet wadding or felt (Fig. 6 D). The felt pieces are held in place with a single layer of sheet wadding.

A team of three applies the plaster. One surgeon is responsible for the head and neck portion and the other two surgeons for the trunk and thighs. Circular and reinforcing plaster splints are used to fashion a strong cast. All sections of the cast are applied simultaneously. Initially, at the head, the plaster is carefully molded under the chin, in the hollow of the neck and over the occiput. The head-piece is then incorporated into the body portion of the cast. If the plaster is not carefully molded and held into the hollow of the neck while it is setting, the chin will drop away from the molded chin-piece after the patient is



Fig 6 MATERIALS AND APPARATUS FOR APPLICATION OF THE TURNBUCKLE CAST

A—Materials (*a*) Aluminum hinges with rivets, (*b*) molded wet chin and neck felt piece, (*c*) six-inch wide felt strips for the torso, (*d*) felt piece for back of head, neck and shoulders, (*e*) padding for the axilla on the convex side of the primary curve, (*f*) small felt piece placed over larynx and withdrawn after completion of cast, (*g*) sheet wadding rolls, (*h*) extra felt pieces for iliac crests in very thin patients and for crest of rib deformity when it is severe, (*i*) long felt piece placed over the irons, (*j*) broom handle for thigh struts, (*k*) stockinet for both thighs, head and neck, and torso

B—Frame with adjustable head-piece set up for application of a cast for correction of a right primary curve Irons are bent to the left

C—Frame taped on Albee-Compere fracture table

D—Patient on frame ready for plaster application

removed from the Goldthwaite frame. An accurately fitting head-piece, from which the chin cannot be pulled down into the neck portion of the cast (Fig. 12 C) is essential to obtain maximum correction with the turnbuckle plaster cast. Both thighs are included within the cast to provide better control of the pelvis.

Rivets, with the heads cut off and the ends filed to a point, inserted in the aluminum hinges provide secure anchoring of the hinges in the plaster (Fig. 6 A, *a*). About half way through the plastering procedure,

the hinges are positioned, one on the anterior and the other on the posterior aspect of the cast. The hinge joint is placed lateral to the apex of the primary curve and the arms adjusted in a closed position (Fig 7 A). The molded head-piece and the hinge positioning exert a distracting as well as a lateral bending force as the turnbuckle is extended. With this technique, the arms of the hinges are not completely straightened at completion of the correction. Thus, the distracting force is exerted throughout the period of correction and is maintained during the postoperative immobilization in the turnbuckle cast.

Correction of Curvature

Six or seven days after application, the plaster is sufficiently dry to allow cutting of the cast. A window is cut in the cast between the anterior and posterior hinge joints on the convex side of the primary curve. The window is placed eccentrically to the hinge joints, in thoracic curves, to leave an adequate bridge of plaster in the axilla (Fig. 7 A). The cast is split on the opposite side between the hinge joints, then manually spread to allow application of lugs and insertion of a small turnbuckle. The turnbuckle is turned up each day as many turns as the patient will tolerate — usually until the patient complains of a pulling or tight sensation on the side being stretched (Fig. 7 B). In the more recent cases, the desired correction has been obtained in seven to ten days without discomfort to the patient. Occasionally, it is necessary to turn back the turnbuckle if, after several hours, there is undue discomfort.

One must be ever watchful for symptoms of pressure. The areas most susceptible to pressure are the sacrum, the spine of the scapulae, the crest of the posterior rib deformity, the anterosuperior spine of the ilium (on the convex side of the primary curve), and the chin. Any complaint of pressure must be investigated by exposing the area, regardless of the thickness of the plaster or the location of the pressure. This is important, since the pressure symptoms, if disregarded for several days, may disappear due to the development of insensible necrotic tissue. Such an unfavorable pressure area may increase in extent and depth without producing further symptoms.

When roentgenographic examination shows that the desired correction has been obtained, the cast is boxed-in and supporting struts are applied to both sides (Fig. 7 C). Several days later, a window is cut in the back of the cast, preparatory to fusion (Fig. 7 D). Over a layer of foam rubber a new lid is fashioned to fit the window. This lid is held in place with heavy canvas straps. A second window is cut in the front of the cast over the chest (Fig. 7 C) to allow emergency exposure of the anterior thorax if necessary.

Since early in 1952, fresh autogenous iliac bone has been used as supplement in the fusion. This necessitates an auxiliary window in the



Fig 7 TURNBUCKLE PLASTER CAST
A—Before starting correction.
B—Turnbuckle wedging in progress.
C—Correction completed, cast is boxed in and struts applied Anterior window is marked out
D—Large posterior window through which operation is performed
E—Twelve days postoperative, wounds are healed. The iliac-sacral lid is replaced firmly with plaster The spinal lid remains removable
F—Lids in place and patient ready for discharge from hospital usually two to three weeks after surgery

cast for exposure of the ilium on the convex side of the bent cast (Fig. 7 D). With this very large window in the back of the cast, the patient sagged down into the cast when lying supine. This caused troublesome chin pressure. Firmly reapplying the iliac sacral lid with circular plaster, immediately postoperatively, has eliminated this difficulty. The spinal lid is secured in place over the dressing with heavy canvas straps (Fig. 7 E, F).

Spine Marker Roentgenogram

A spine marker roentgenogram is made preoperatively (Fig. 4 C) After injection of a small amount of Procaine®, the area of skin, subcutaneous tissues, and the tip of a spinous process at or near the distal end of the proposed fusion area are marked by injection of one cc. of sterile Methylene Blue using sterile precautions.[4] A metallic marker is placed over this spot and a roentgenogram is made. This allows positive identification of the spinous process at operation and insures proper placement of the fusion area.

INDICATIONS FOR SURGICAL TREATMENT

The indications for operation in the idiopathic cases were an increasing deformity before the completion of spinal growth; an unsightly correctible deformity at or after maturity; the presence of pain — this was the presenting complaint in two adult patients.

In the four cases which were congenital, surgery was performed because of the degree of deformity. In the paralytic cases, progression of the curve, the degree of deformity, and the instability of the trunk due to muscle weakness were considered indications for surgical treatment.

CHAPTER IV

Surgical Technique

THE FUSION OPERATION

THE TECHNIQUE of spinal fusion has remained basically the same through the years. However, an increasing experience has resulted in better technical performance and, therefore, better fusions in the patients operated on in recent years. In the past five years, the spine has been exposed more widely than previously. Secondly, the type of supplementary bone added to the fusion has been changed From 1939 through 1947, tibial osteoperiosteal grafts were used. Supplementary banked bone chips were used in the fusion in a group of cases treated from 1948 through 1951. Since early in 1952, fresh autogenous iliac bone has been used almost exclusively.

The operation is performed through a large posterior window in the boxed-in turnbuckle cast (Fig. 7 D). Adrenalin solution, 1:200,000 in physiological saline, which acts as a hemostatic agent, is injected into subcutaneous and fascial tissues along the line of the proposed iliac and spinal incisions. Next, the ilium is widely exposed subperiosteally through an incision parallel to the posterior two-thirds of the crest (Fig. 8 A). Rectangles of cortex are removed from the posterior two-thirds of the outer table of the ilium (Fig. 8 B). With a hand gouge cancellous bone is then peeled off the ilium in long strips from the entire exposed surface. A large quantity of supplementary bone is thus obtained for use in the fusion (Fig. 9). The cortical blocks are cut into match-stick size and the cancellous strips are used as removed. This wound is closed to the subcutaneous tissues.

The spine is then exposed through a straight linear incision on the concave side of the corrected curve, as suggested by Cobb. The soft tissue structures are reflected subperiosteally from the spinous processes and laminae, carrying the exposure out over the transverse process in the thoracic spine and over the facet joints in the lumbar area. Bleeding is controlled with the electrocautery. Meticulous removal of all soft tissue is carried out and the tips of the spinous processes are clipped off. Then with a razor-sharp hand gouge, bone flaps are turned down from the spinous processes, laminae, and transverse processes. The gouge cuts deeply, reflecting the full thickness of the posterior

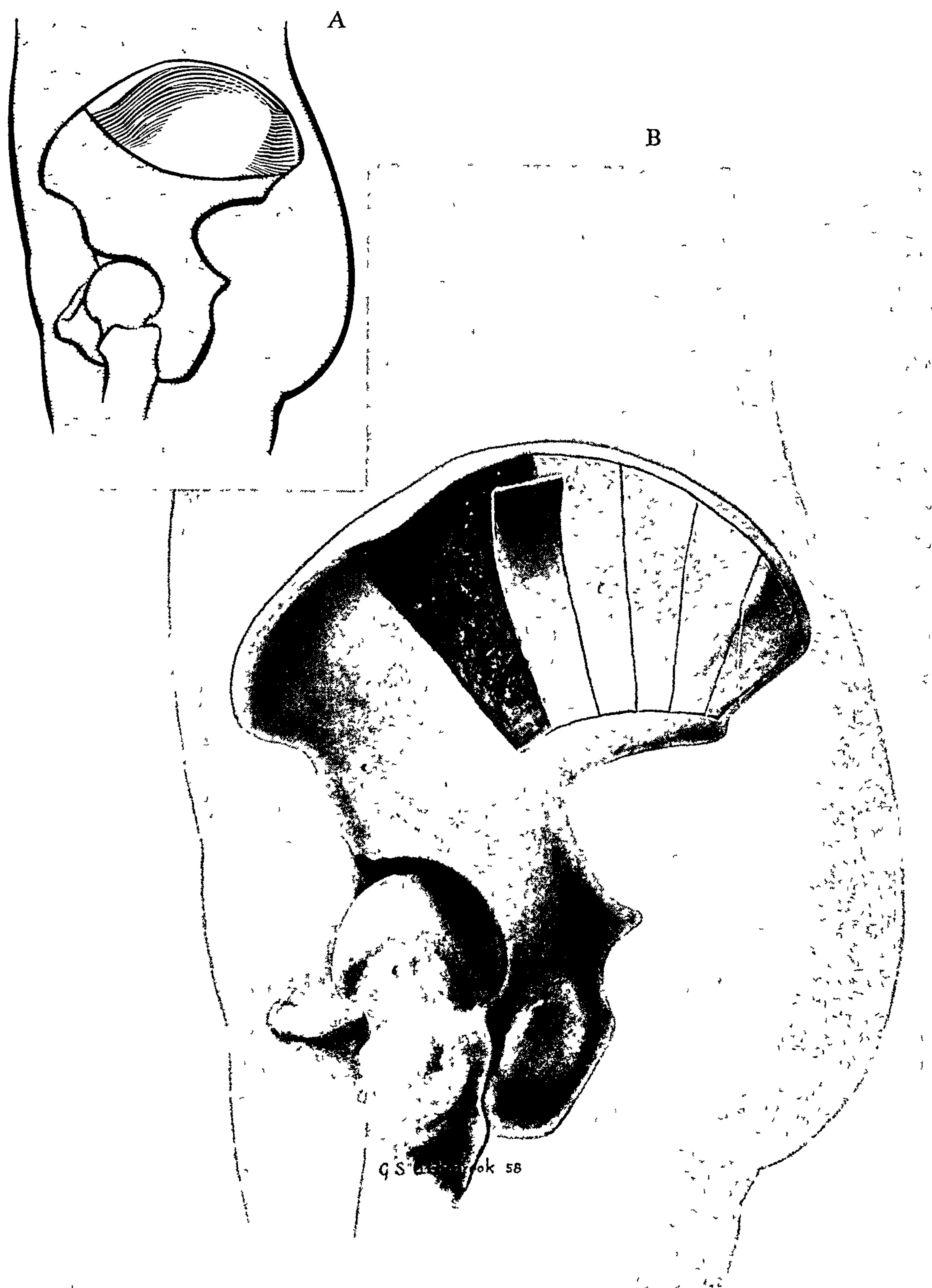


Fig. 8. Diagram of Graft Donor Site
A—Exposure of outer table of ilium
B—Area of bone removed from ilium. Cortical rectangles are first removed, then all the exposed underlying cancellous bone is taken

cortex from the lamina and transverse process, and turning down the entire spinous process which results in maximum width of exposed raw bony surface.

Careful and precise technique is important. The gouge is controlled with both hands. Firm pressure is applied simultaneously with a short



FIG 9 AVERAGE AMOUNT OF CORTICAL AND CANCELLOUS BONE OBTAINED FROM ONE ILIUM

twisting motion reflecting the bone flap. A very sharp instrument is essential. Several gouges, reserved for use in scoliosis fusions only, are always sharpened before each operation. As soon as a gouge begins to show evidence of losing its sharp cutting edge, a second instrument is substituted.

The flaps of bone thus obtained are laid down along the more lateral aspects of the fusion area, covering the interlaminar spaces with the cortical side of the bone flap turned ventrally (Fig. 10). No attempt is made to interlock the bone flaps or to keep them attached at their base or to preserve any portion of the spinous process of the end vertebra. In the lumbar spine, the bone flap is carried as far laterally as possible, crossing the exposed facets. The iliac bone is then laid down over the fusion area — first the cancellous and then the cortical grafts. The wound is closed in layers.

The iliac sacral lid is firmly reapplied with plaster immediately postoperatively. Otherwise, because of the large window in the back of the cast the patient would sag down when lying supine. This caused troublesome skin pressure, particularly during the first few postoperative days.

The use of the mallet is avoided because it contributes to shock. The hand gouge technique and replacement of blood as it is lost, usually three pints during surgery, has permitted routine one-stage operations. The hand gouge technic of spine fusion was demonstrated to me in 1937 by Dr. Joseph Barr at the Massachusetts General Hospital.

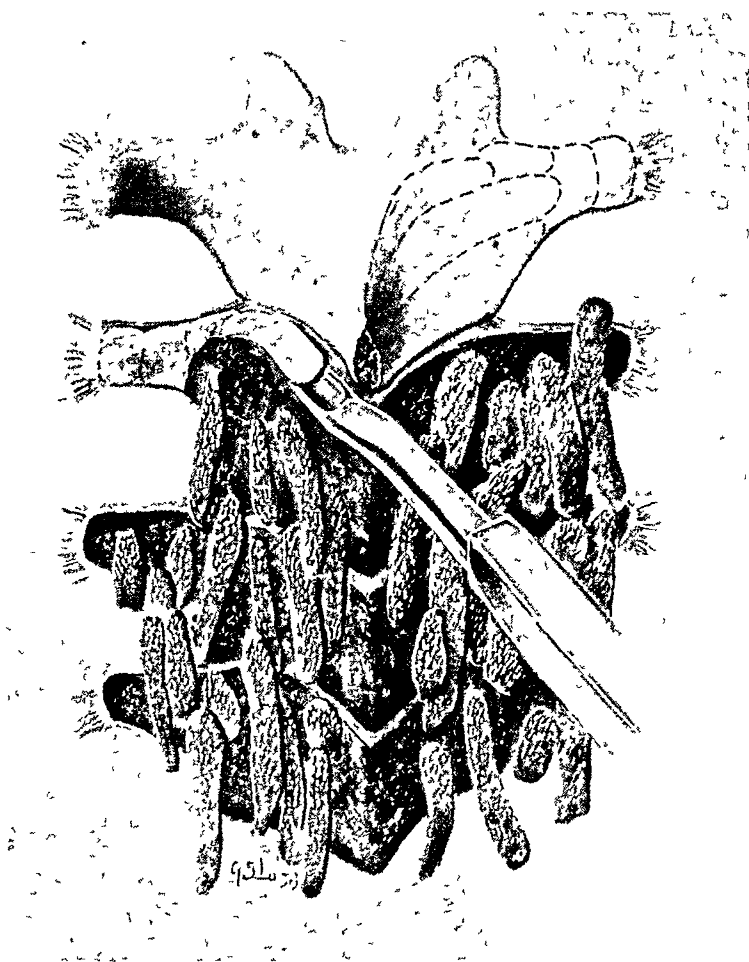


FIG 10 COMPOSITE DIAGRAM TO SHOW TECHNIQUE OF FUSION Complete decortication of laminae and transverse processes, spinous processes turned down. Bone flaps detached and laid down over the more lateral aspects of the fusion area The supplementary cancellous and cortical iliac grafts are then laid down over this entire area (these grafts are not shown)

In the series of cases analyzed, an average of seven to nine vertebrae, and in two patients eleven vertebrae, have been fused in one stage. Forty-one patients of the series had a one-stage operation. Eight patients were operated on in two stages and one patient in three stages. In four patients bone was removed from both iliac crests prior to application of the turnbuckle cast, and placed in the bone bank. The curvature was then corrected in a turnbuckle cast, and the banked autogenous iliac bone was used in the fusion which was subsequently performed in one stage

CHAPTER V

Postoperative Management

POSTOPERATIVE TREATMENT

IMMOBILIZATION IN THE turnbuckle cast is continued for six months after operation. The patients usually are discharged from the hospital two to three weeks after operation. The New York State Crippled Children's Program provides a home tutor so that education is not significantly interrupted. Six months after operation, the patient is readmitted to the hospital and the turnbuckle cast is removed. The status of the fusion is evaluated roentgenographically and a bent cast is applied, including one thigh and a single shoulder strap, for two more months of recumbency at home (Fig. 11 A). Following this, an ambulatory bent cast with one shoulder strap is worn for two more months (Fig. 11 B). The patient is then freed of all support. In several of the paralytic cases, with severe trunk involvement, wearing a removable celluloid jacket was continued for longer periods (Fig. 11 C).

EXERCISES DURING IMMOBILIZATION

During the period of immobilization in the turnbuckle plaster cast, certain deformities are apt to occur. These can be prevented by simple exercises.

A well-molded, snugly fitting head-piece on the turnbuckle plaster cast produces a more or less constant upward pressure on the chin, and hence may give rise to temporomandibular joint pain and malocclusion. We have seen a patient develop a fixed deviation of the jaw in a relatively short time. Some children choose to lie in the most comfortable position such as turned on the left side when a right thoracic curvature is being corrected. The chin thus rests against the left side of the plaster head-piece and the mandible is pushed toward the right.

To prevent these complications, the patient is instructed in specific forms of exercises: the chin elevated out of its rest allows the mouth to be opened widely and the mandible deviated first to the right and then to the left (Fig. 12). This exercise routine, repeated six times daily, is established before starting the correction, because the chin becomes more tightly pressed against the chin rest as the distracting and lateral bending forces come into play with turnbuckle wedging.

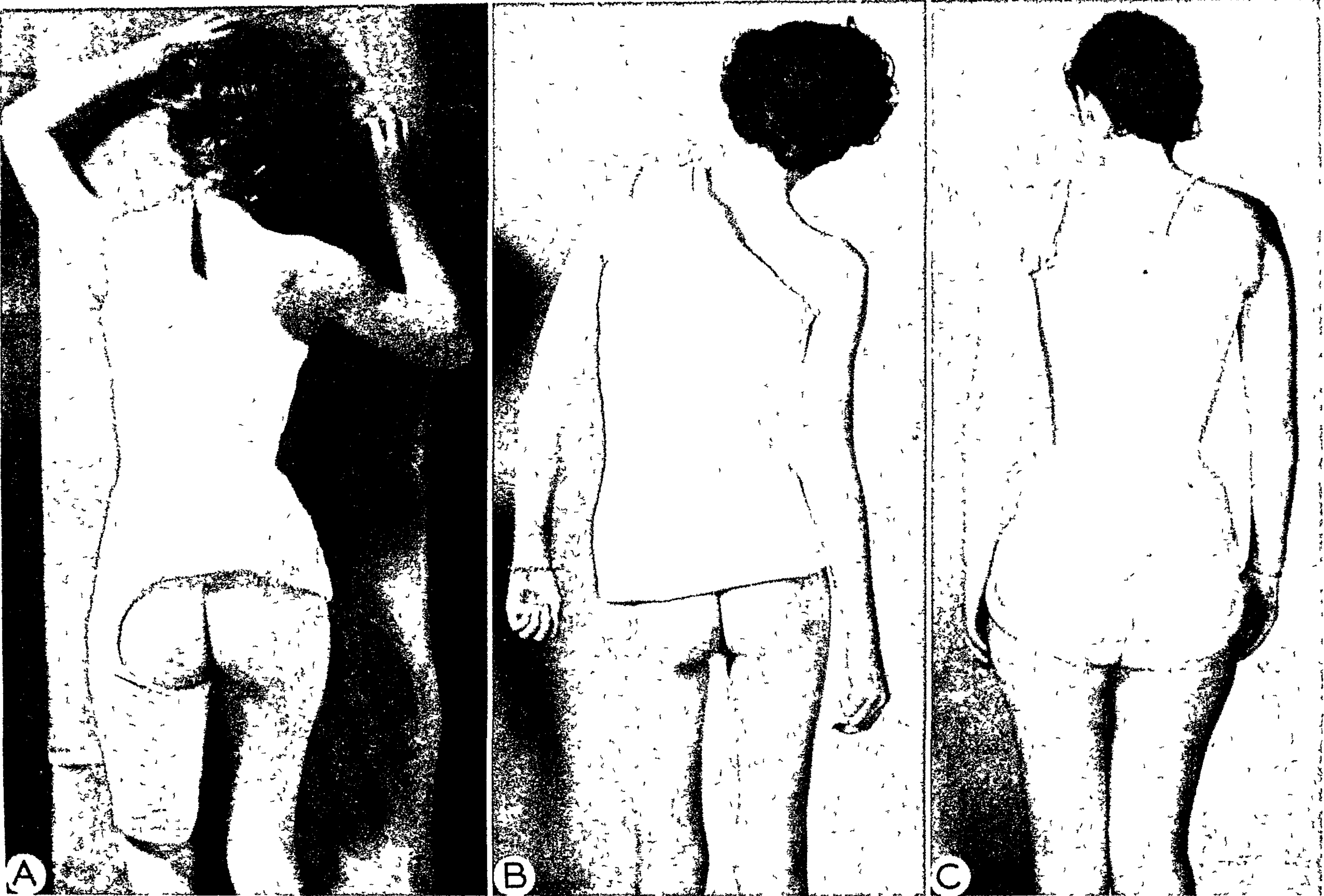


Fig 11 Bent Casts and Removable Jacket
A—Bent plaster cast applied at six months postoperative
B—Ambulatory bent plaster cast applied eight months after surgery
C—Removable celluloid jacket



Fig 12 Details of the Turnbuckle Cast Headpiece
A—Chin at rest
B—Chin elevated
C—Chin depressed Note that patient cannot pull chin down into neck portion of cast This insures an effective distraction force during correction
D,E,F—Jaw exercises for prevention of temporomandibular joint arthralgia and malocclusion

The patients are prompted to carry out the exercises daily. Frequent changes of position plus jaw exercises prevent the development of malocclusion.

All patients are required to exercise their knees, ankles, and feet. This is especially important in paralytic cases, because troublesome knee flexion and ankle and tarsal deformities may develop insidiously during the postoperative recumbent period. Active quadriceps exercises to maintain complete knee extension and flexion exercises are pre-

scribed.

In the presence of quadriceps muscle weakness or paralysis, daily passive exercises to maintain a full range of knee motion are performed. Active dorsiflexion of the foot as well as passive exercises for stretching of the calf structures prevents the development of equinus deformity. Splints are used where indicated.

The patients are encouraged to use a trapeze suspended from an overhead frame to help in their nursing care and also to maintain muscle tone and strength in the upper extremities. Two or three weeks following spine fusion, the children are discharged from the hospital in the turnbuckle plaster cast. Convalescence is continued at home in a hospital bed with overhead frame and trapeze. Most of the children are very active during the period of immobilization in the turnbuckle plaster cast after they have recovered from the immediate effects of the spine fusion. This activity is encouraged.

Following the long period in recumbency, some of the paralytic patients with residual lower extremity muscle weakness or paralysis require gait training, first on parallel bars and then on crutches. All plaster immobilization is usually discontinued at about ten months after fusion. The children are allowed to increase their activity as tolerated. Most patients promptly recover from the bent position without special exercises or treatment. The usual daily activities mobilize the unfused portion of the spine adequately so that no special efforts have been made to exercise the trunk other than to encourage gradually increasing activity. Those few patients who are slow in overcoming the bent position are instructed in a simple exercise routine consisting of posturing in front of a mirror, leveling the shoulders and attempting to square the head and shoulders over the pelvis.

COMPLICATIONS

Early in this experience brachial plexus pressure with partial motor and sensory loss occurred in two patients due to pressure of the headpiece against the side of the neck. Complete and prompt recovery followed release of the pressure. Flexion of the head toward the concavity of the primary curve when applying the turnbuckle cast, and careful attention to the molding of the plaster around the head and neck have eliminated this complication. In several of the early cases, deep pressure areas developed. With experience in application of the cast, and with prompt attention to the patient's complaints, this is no longer a problem.

Malocclusion, which is apt to occur because of the distracting force exerted during wedging of the turnbuckle cast, is prevented by the regular jaw exercise routine carried out by the patient throughout the period of immobilization in the turnbuckle cast.

In one patient, a respiratory difficulty developed one hour postoperatively which required a tracheotomy. Removal of the tracheotomy tube nine days later was followed by uneventful recovery.

Another patient had massive gastrointestinal hemorrhage on the eighth postoperative day. Ten pints of blood were required to stabilize the blood pressure over a twenty-four hour period. The preoperative diagnosis was stress ulcer but at operation a severe hemorrhagic gastritis was found. A subtotal gastrectomy was followed by an uneventful recovery.

In three cases a major postoperative wound infection occurred. In two of these patients, the fusion was solid with maintenance of correction, in the third patient, a pseudarthrosis developed with loss of correction.

No deaths occurred.

CHAPTER VI

Results of Surgical Treatment

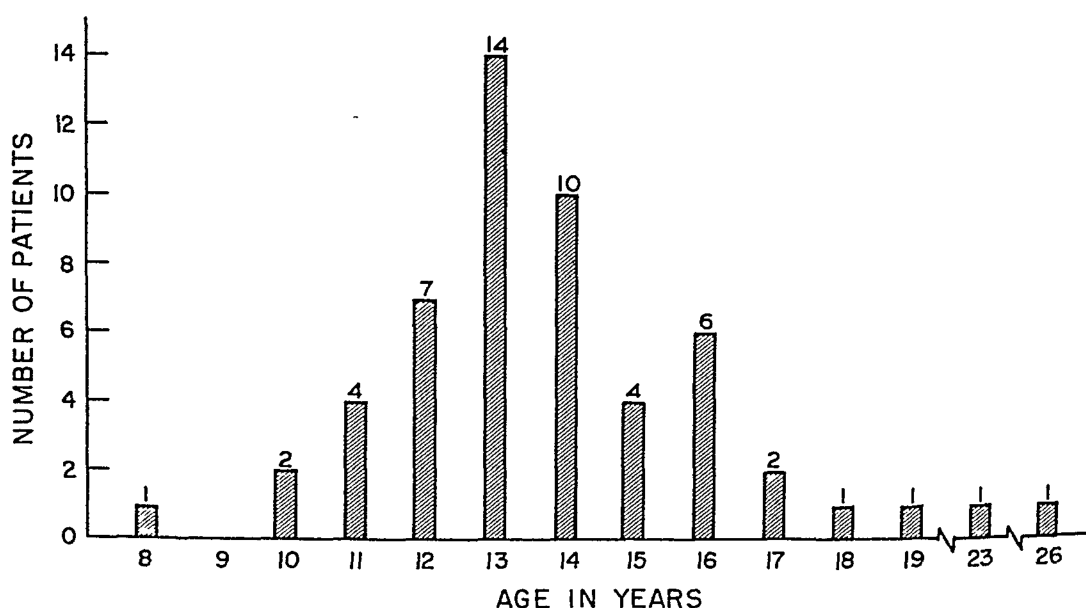
IN THIS CHAPTER the incidence of pseudarthrosis and the loss of correction are analyzed in relation to the etiology of the curvature and to the type of supplementary bone graft used in the fusion.

MATERIAL

Sixty-five patients have been treated by turnbuckle cast correction of the curvature and spinal fusion. Sufficient time had elapsed to allow evaluation of the results in fifty-four consecutively treated cases. Fifty-two patients were followed for two years or more and two for eighteen months. The longest follow-up was seventeen years and eight months.

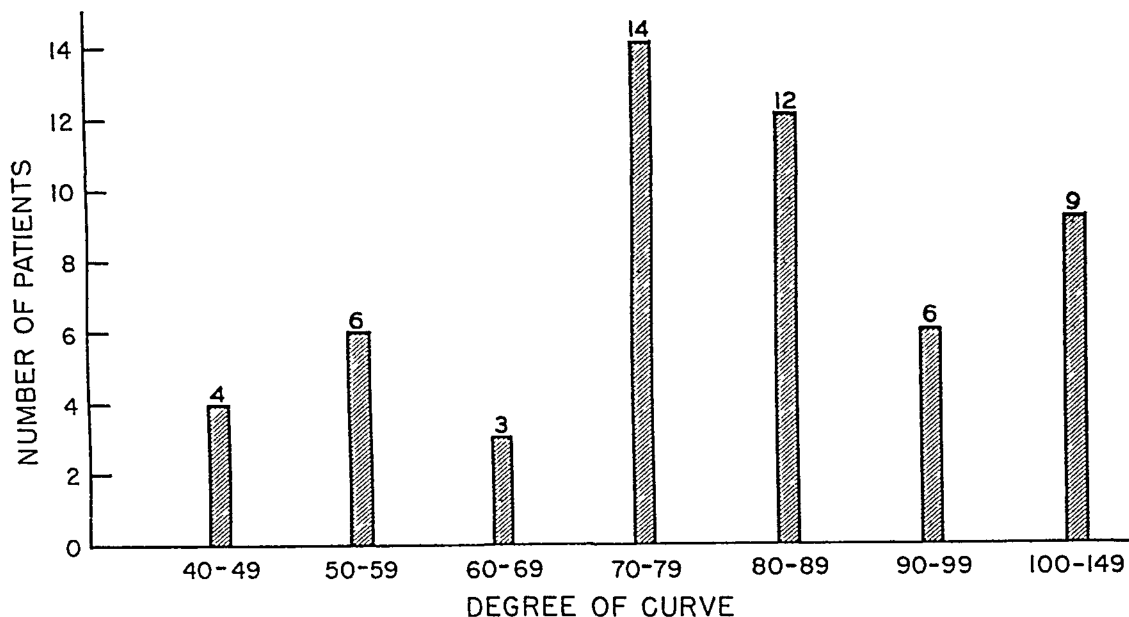
CHART I

AGE AT OPERATION



The age of the patient at the time of operation varied from eight years and eleven months to twenty-six years (Chart I). There was only one patient under ten years of age (eight years and eleven months). Two patients were in the tenth year, four in the eleventh, and seven in the twelfth year Thirty-four of the patients (60 per cent) were between

thirteen and seventeen years of age. Six patients were over seventeen years of age. The distribution of patients according to the severity of the curvature is shown on Chart II. Seventy-five per cent of the curves measured 70 degrees or more.



DETERMINATION OF LOSS OF CORRECTION

The preoperative maximum deformity is the angle of the curvature measured on a roentgenogram of the spine made in the erect position (Fig. 13 A). The "correction obtained" represents the measurement of the curvature on the last preoperative roentgenogram, which is made with the plaster lid removed to better visualize the spine (Fig. 13 B). The total correction is obtained before fusion is performed. The degree of loss of correction is determined by measurement of the fused primary curve in the latest roentgenogram with the patient in the upright posture without wearing an apparatus (Fig. 13 C). Oblique roentgenograms of the spine were made to better visualize the fusion mass (Fig. 14).

GENERAL CONSIDERATIONS

The presence of pseudarthrosis was suspected when significant and progressive loss of correction was observed on the anteroposterior roentgenogram of the spine and was at times confirmed by lines of decreased density in the fusion mass in the oblique views.

In fifty-four consecutive cases, there were seven pseudarthroses, an incidence of 13 per cent (Table I). Two of these pseudarthroses occurred in the three cases of congenital curvature. One patient in whom a supplementary osteoperiosteal graft was used in the fusion had a wide

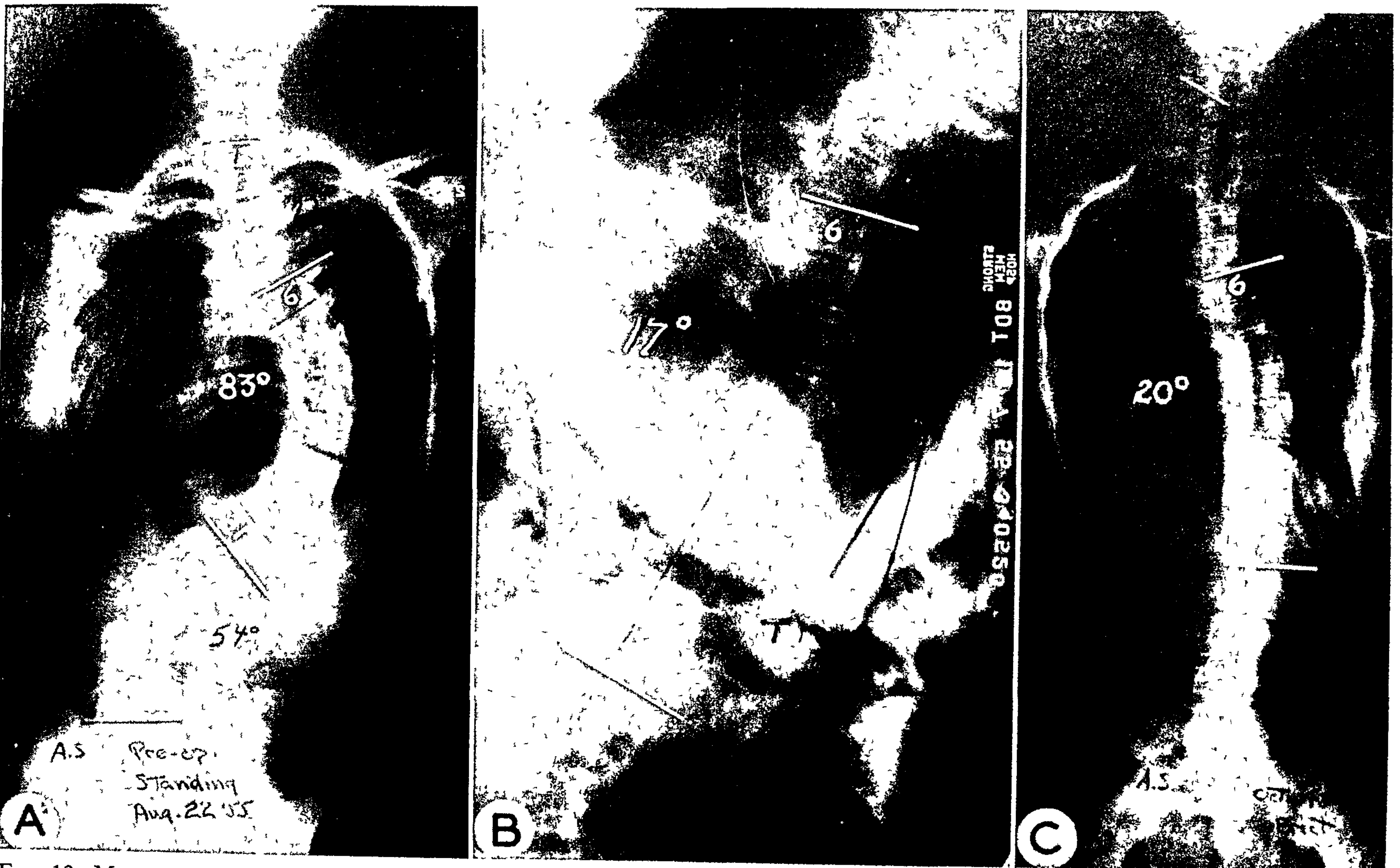


Fig 13 Method of Determination of Loss of Correction in the Fusion Area.

A—An idiopathic right thoracic curve before correction

B—Preoperative correction of the curvature in turnbuckle plaster cast Residual curve 17 degrees This is the "spine marker" roentgenogram The opaque marker is on the spinous process of the twelfth thoracic vertebra.

C—Two years postoperative, residual curve 20 degrees, 3 degree loss of correction

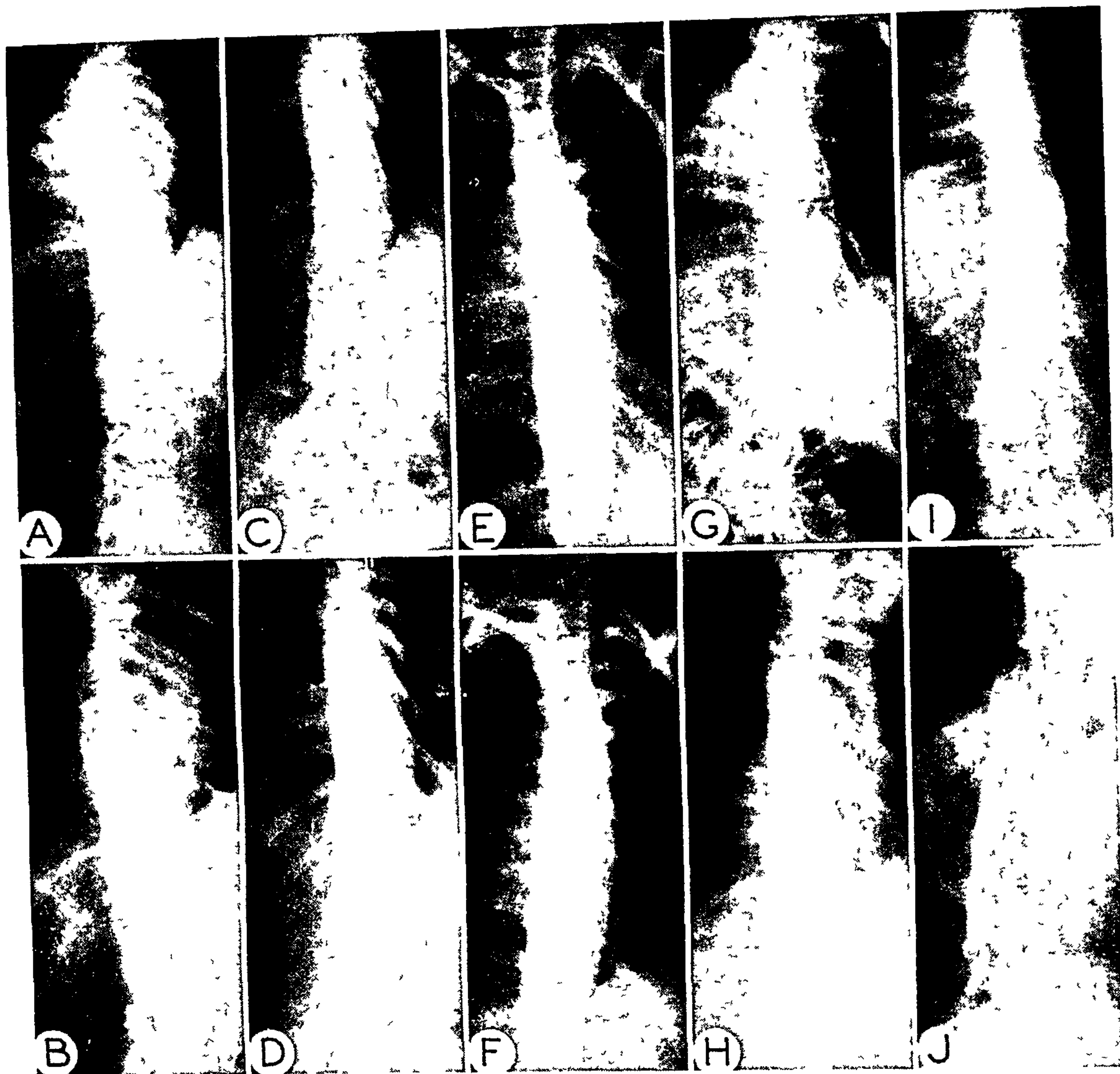


Fig 14 FUSION WITH FRESH AUTOGENOUS ILIUM SUPPLEMENT Oblique views of the fusion area in five patients

Case A Hag	A—Six months postoperative
	B—One year and six months postoperative
Case N C	C—Six months postoperative
	D—Two years and six months postoperative
Case D G	E—Six months postoperative
	F—Four years and five months postoperative
Case T F	G—Seven months postoperative
	H—Four years postoperative
Case C Rob	I—Seven months postoperative
	J—Five years postoperative

spina bifida extending from the tenth thoracic vertebra to the sacrum. Another patient with banked bone fusion had poorly developed posterior vertebral arch structures which provided a poor base for a satisfactory fusion. These cases did not afford a true test of the method. An analysis of the fifty-one idiopathic and paralytic cases follows.

IDIOPATHIC AND PARALYTIC SCOLIOSIS

Pseudarthrosis

Of thirty-one patients with idiopathic scoliosis, a pseudarthrosis developed in three; of twenty with paralytic curvatures, pseudarthrosis developed in two patients (Table I).

The incidence of pseudarthrosis in the fifty-one cases of idiopathic and paralytic scoliosis are further analyzed in relation to the type of supplementary bone used in the fusion and are divided into two main

TABLE I

INCIDENCE OF PSEUDARTHROSIS IN 51 CASES OF IDIOPATHIC AND PARALYTIC SCOLIOSIS

	Cases	*Pseud.*	*Per Cent*
Etiology			
Idiopathic	31	3	10
Paralytic	20	2	10
Type of Graft			
All other type grafts*	26	4	15
Fresh autogenous ilium	25	1	4

Includes osteoperiosteal, banked homogenous bone, and banked autogenous ilium

categories. In the earlier fusions, osteoperiosteal, banked homogenous bone, banked autogenous ilium, or a combination of any two of these were used as supplementary grafts. These are referred to below in Group I as *"all other type grafts."* For six years *fresh autogenous ilium* (Group II) has been used to supplement the fusion.

Group I. *Fusion with all other type grafts*: There were twenty-six patients in this group with four pseudarthroses, an incidence of 15 per cent.

Group II. *Fusion with fresh autogenous ilium*: There were twenty-five patients in this group with one pseudarthrosis, an incidence of 4 per cent This pseudarthrosis in *Case S. L.* occurred at the last joint in the fusion area of an idiopathic thoracic curve. Spontaneous healing supervened with 14 degrees loss of correction (Table II).

*See *Addendum*, page 94

Loss of Correction

Fifty-one cases of idiopathic and paralytic scoliosis are analyzed with regard to the loss of correction and type of bone graft.

Group I. *Fusion with all other type grafts.* The angular values of the curvature in the twenty-six patients in this group varied from 42 degrees to 148 degrees. Ten patients had curves measuring less than 70 degrees and sixteen had curvatures of 70 degrees or greater.

Fifteen patients lost 15 degrees or less and seven patients lost between 16 degrees and 24 degrees in correction. The four with pseudarthroses showed the following losses: 23 degrees; 31 degrees; 55 degrees, and 57 degrees (Table II).

TABLE II
LOSS OF CORRECTION
IN 51 CASES OF
IDIOPATHIC AND PARALYTIC SCOLIOSIS

All Other Type Grafts*—26 Cases		Fresh Autogenous Ilium—25 Cases	
Cases	*Loss*	*Cases*	*Loss*
15	15° or less	22	10° or less
7	16°-24°	1	12°
4 pseud	23°, 31°, 55°, 57°	1	23°
		1 pseud (Spontaneous healing)	14°

*Includes osteoperiosteal, banked homogenous bone, and banked autogenous ilium

The correction gained preoperatively expressed in per cent of the precorrection angular deformity was as follows (Chart III): One curvature was corrected 39 per cent, six were corrected 40 to 49 per cent, two were corrected 50 to 59 per cent, four were corrected 60 to 69 per cent, six were corrected 70 to 79 per cent, five were corrected 80 to 89 per cent; one was corrected 91 per cent, and one 93 per cent.

The per cent loss of preoperatively gained correction was as follows (Chart IV): Three patients lost 10 per cent or less; seven patients lost 11 to 21 per cent; five patients lost 22 to 31 per cent; and in five patients the loss in correction was 32 to 41 per cent. One patient lost 54 per cent and another 92 per cent. In this last case, the head-piece was removed from the turnbuckle cast one week after the fusion operation to relieve brachial plexus pressure which unfortunately eliminated the distraction element of the forces exerted in the cast. This patient, an adult, was ambulant four months after operation.

The four patients in whom pseudarthrosis developed lost 29 per cent, 50 per cent, 100 per cent, and 89 per cent of correction respectively.

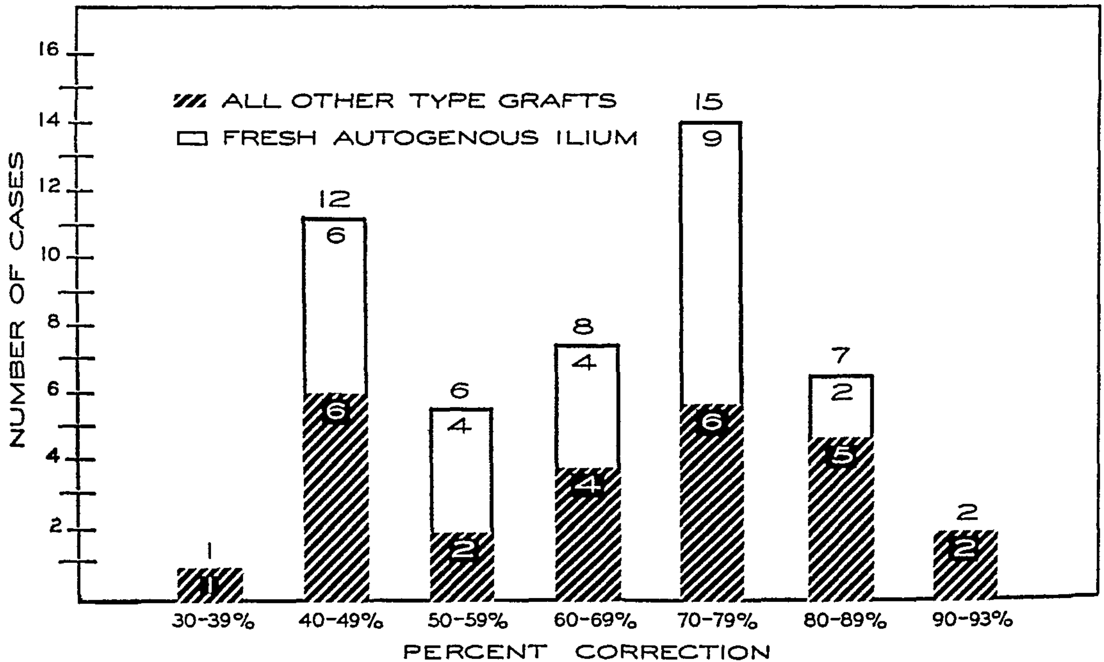
The patient who lost only 29 per cent in correction had surgical repair of a pseudarthrosis one year after the surgery.

Group II. *Fusion with fresh autogenous ilium*: The angular values of the precorrection curvature in the twenty-five cases in this group varied from 63 to 122 degrees. Three curves measured between 63 and 68 degrees; all others were 70 degrees or more.

CHART III

IDIOPATHIC AND PARALYTIC SCOLIOSIS 51 CASES

CORRECTION GAINED PREOPERATIVELY



Twenty-two patients lost 10 degrees or less in correction, and one patient lost 12 degrees (Table II). The curvature in the other patient (*Case D. Sey.*, Table III) showed a 23-degree loss. This fifteen year old boy had a 75-degree rigid left thoracic curvature that was corrected to 33 degrees preoperatively. There was a 3-degree loss of correction measured in the turnbuckle plaster cast. He walked at six months after operation directly after removal of the turnbuckle plaster cast. During the next six months, there was an 18-degree loss in correction and a 2-degree loss during the second postoperative year. Oblique roentgenograms of the fusion area made at each stage in the postoperative follow-up failed to reveal any evidence of pseudarthrosis. The loss of correction occurred uniformly through the fusion area due to bending in the graft.

The only patient in this group in whom pseudarthrosis occurred (*Case S. L.*, Fig. 22), also became ambulant six months after operation.

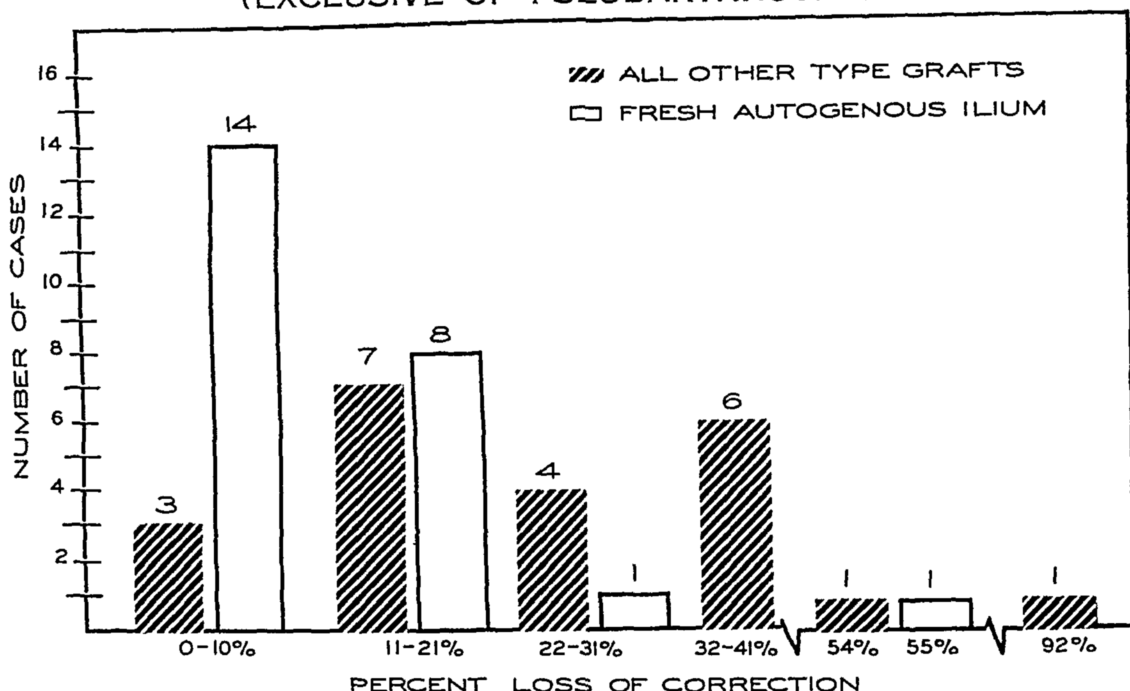
The per cent correction which had been gained preoperatively was as follows (Chart III): Six curvatures were corrected 40 to 49 per cent; four were corrected 50 to 59 per cent; four were corrected 60 to

69 per cent; nine were corrected 70 to 79 per cent; and two curves were corrected between 80 and 89 per cent.

The per cent loss of preoperatively gained correction (Chart IV) was 10 per cent or less in fourteen cases, between 11 and 21 per cent in eight cases. One patient lost 25 per cent and another lost 55 per cent. In the one curvature in which a pseudarthrosis developed there was a loss of 26 per cent.

CHART IV

PERCENT LOSS OF CORRECTION
(EXCLUSIVE OF PSEUDARTHROSES)



This group of cases was further studied in relation to the loss of correction which occurred between the time of removal of the Risser cast at six months and one year postoperative. Twenty-three of the twenty-five patients lost less than 10 degrees or 12 per cent in correction during this six-month period. The patient (*Case S. L.*, previously mentioned), in whom a pseudarthrosis developed, lost 14 degrees (26 per cent) during this period. The other patient in this group (*Case D. Sey.*, discussed earlier) lost 18 degrees (37 per cent).

After the first postoperative year, no further loss greater than 6 degrees or 11 per cent of preoperatively gained correction was measured in the fusion area in this group of cases. It became evident, therefore, that this type of fusion has sufficiently matured at the end of the first postoperative year to hold correction without further significant loss. There were no graft fractures or so-called delayed pseudarthroses observed after the first postoperative year. The longest follow-up in this group of cases was five years and eight months.

Data regarding loss of correction in patients having fusion with fresh autogenous ilium are summarized in Table III.

TABLE III

AUTOGENOUS ILIUM

*Per cent pre-op Correction**	*Per cent Loss of Correction*†	*Age at Operation (yr + mo)*	*Months Recumbent*	*Status of Fusion*	*Etiology*
76	**2**	16+0	*8*	solid	idio.
43	**6**	16+0	*8½*	solid	paral.
70	**20**	13+0	*9½*	solid	idio.
52	**11**	12+10	*8*	solid	idio
67	**15**	13+6	*9½*	solid	idio
54	**25**	14+9	*8½*	solid	idio.
80	**8**	13+0	*8*	solid	idio.
53	**10**	13+5	*8*	solid	idio.
77	**26**	14+10	*6½*	pseud. healed	idio
56	**55**	15+3	*6*	solid	idio.
69	**17**	13+11	*6*	solid	idio.
79	**4**	12+5	*6*	solid	idio.
67	**13**	11+6	*6*	solid	idio.
49	**5**	16+4	*6*	solid	idio.
44	**21**	12+11	*9½*	solid	idio.
43	**7**	12+6	*6*	solid	idio.
71	**9**	13+0	*7*	solid	paral.
60	**18**	14+5	*9*	solid	paral.
71	**0**	15+5	*7*	solid	paral
82	**7**	14+11	*9*	solid	paral
73	**12**	16+0	*6*	solid	paral.
70	**6**	11+5	*6½*	solid	paral
47	**0**	12+8	*8*	solid	idio
47	**2**	14+7	*8*	solid	idio
75	**9**	13+11	*8*	solid	idio.

†Loss of correction (per cent) = $\frac{\text{Final curve} - \text{preoperative curve}}{\text{Total correction obtained (original curve} - \text{preoperative curve)}} \times 100$

CHAPTER VII

Analysis of End Results in Relation to Etiology and Curve Pattern

END RESULTS OF SURGICAL TREATMENT

THE FINAL RESULTS of surgical treatment in these cases of scoliosis were influenced by the following: The degree of correction obtained; the technique of spinal fusion, the duration of immobilization and recumbency; maintenance of correction; and the age of the patient when the operation was performed.

The desired degree of correction as determined by the criteria discussed in Chapter III was uniformly accomplished preoperatively in the turnbuckle plaster cast *Over-correction of the primary curve in relation to the fixed angulation in the compensatory counter curves is to be avoided.*

It is generally agreed that a fusion of the spine is necessary to maintain correction. In order to perform this function effectively, the fusion must be solid, it must be massive enough to withstand the stresses to which it is subjected upon removal of the immobilizing apparatus, and it must include at least all of the vertebrae in the primary curve. The fusion technique used in these cases supplemented by a massive amount of fresh autogenous iliac bone resulted in a fusion mass that had sufficiently matured at one year postoperative to hold correction.

This experience indicates that six months' postoperative immobilization in the turnbuckle plaster cast, followed by two more months in recumbency in a bent cast and finally two months in an ambulatory plaster jacket insures retention of correction in those cases that have a solid fusion.

The age at which a scoliotic patient should be operated upon remains a debatable question. Correction and fusion at or after bone maturity allows more accurate prediction of the end result if the desired correction is obtained and a solid massive fusion is accomplished than when surgical treatment is undertaken at an earlier age. Furthermore, surgical treatment of the young child before completion of the period of rapid spinal growth is always attended by the hazard of unpredictable changes

in the spinal curves beyond the fusion area during the postoperative period of further spinal growth. Therefore, the end result cannot be predicted as well in the surgically treated young child as when operation is performed in the patient at or near bone maturity.

IDIOPATHIC SCOLIOSIS

The results in the children with idiopathic scoliosis are analyzed and discussed in relation to the curve patterns in these patients according to the classification on page 11.

Main Lumbar Curve

Patients with this curve pattern rarely develop a degree of deformity that warrants surgical interference. Ponseti and Friedman, in 1950, pointed out that the main lumbar curve is the most benign of all of the idiopathic curvatures. These curves usually have their onset during the adolescent years and do not progress to a severe deformity. Even in the patients who develop an angular deformity of 70 degrees or more, the clinical appearance is not grossly disturbed, because of the absence of rib rotational deformities, and because the shoulders remain level and the head well centered over the pelvis. Backache in the adult years is, however, a very common complaint. In James' series,[14] thirty-nine patients with main lumbar curve who were over twenty-five years of age all had backache. This appears to be due to the development of severe degenerative arthritic changes involving the apophyseal joints.

Illustrative Case

One patient (*Case L. P*, Table IV) in this group was operated on in 1946. A curve of 52 degrees was corrected to 7 degrees and correction maintained at 17 degrees. Other similar deformities seen since 1946 have not been subjected to surgical treatment

Thoracolumbar Curve

This curve pattern usually has a relatively late onset and progresses slowly. A deformity severe enough to warrant surgical treatment does not develop in many patients with this curve pattern. In the few cases that require correction and fusion, the operation can usually be delayed to or near the completion of spinal growth. When fusion is done at this stage in the evolution of the curve, the end result is more certain, because the unpredictable future deformity associated with spinal growth is no longer a factor. Fusion limited to the vertebrae in the primary curve is satisfactory for maintenance of correction.

There were five children and one adult in this group. The primary curve alone was fused in four patients; the primary curve plus one vertebra in one case; the primary curve plus one vertebra above and one

below were included in the fusion in the sixth patient. Follow-up of two patients was too brief for evaluation. In three children, two fusions are solid and correction maintained. In the other patient (*Case R. M.*, Fig. 15) pseudarthrosis developed and correction was lost.

Fig 15 *Case R M* IDIOPATHIC SCOLIOSIS THORACOLUMBAR CURVE Age at operation — thirteen years and one month Supplementary bone used — banked bone chips

A,B,C—Preoperative

D,E,F—Eleven months postoperative

G,H,I—Three years postoperative

The precorrection primary curve measured 95 degrees, this was corrected preoperatively to a residual curve of 43 degrees Pseudarthrosis developed, resulting in loss of correction and a final curvature of 88 degrees

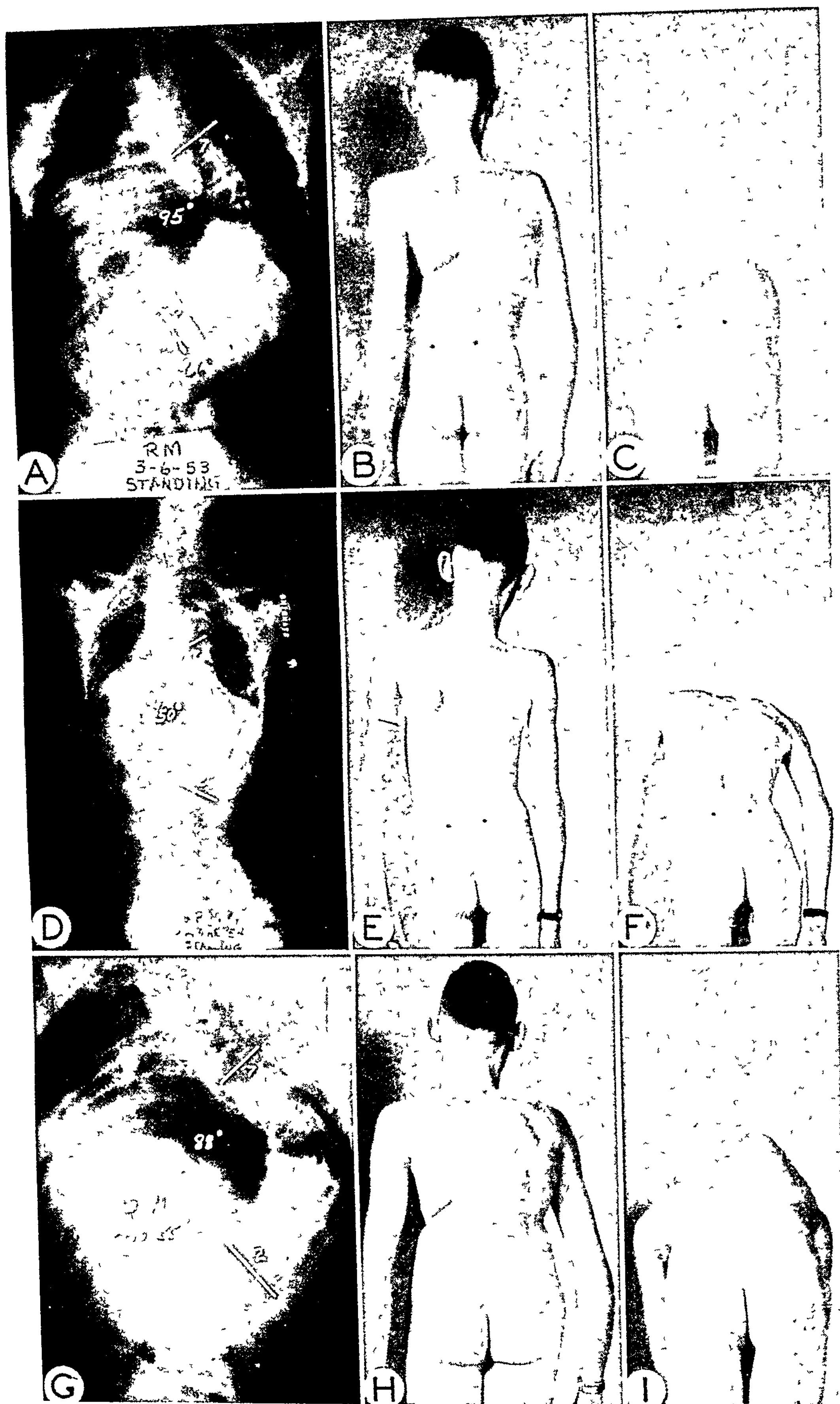


Fig 15 (*Legend on facing page*)

Illustrative Cases — Thoracolumbar Curve

The adult (*Case M J*, Table IV) who was the second patient operated upon in this series, had a fusion because of pain The fusion remains solid and the symptoms are relieved It was necessary to remove the head-piece of the turnbuckle plaster cast shortly after operation because of brachial plexus pressure Complete and prompt recovery of the motor sensory deficit followed Considerable loss of correction occurred, however, because of elimination of the distracting factor which is important in maintaining correction postoperatively as well as in obtaining correction preoperatively

Case N C (Fig 16) This patient was followed during the growth period, at the age of fifteen, one year prior to surgery, the primary curve measured 65 degrees The patient and her parents were advised that there would be no further significant increase in the deformity The decision regarding surgery could be made, therefore, on the basis of the existing condition The deformity, of only moderate degree, was nevertheless of very considerable concern and distress to both the child and her parents. After one year of thought, discussion and consultation, the parents and the patient decided to have surgery performed Similar deformities in other patients have not been operated upon because the parents and the child were not distressed by the deformity and were willing to accept the abnormal appearance of the trunk rather than to undertake a major surgical venture.

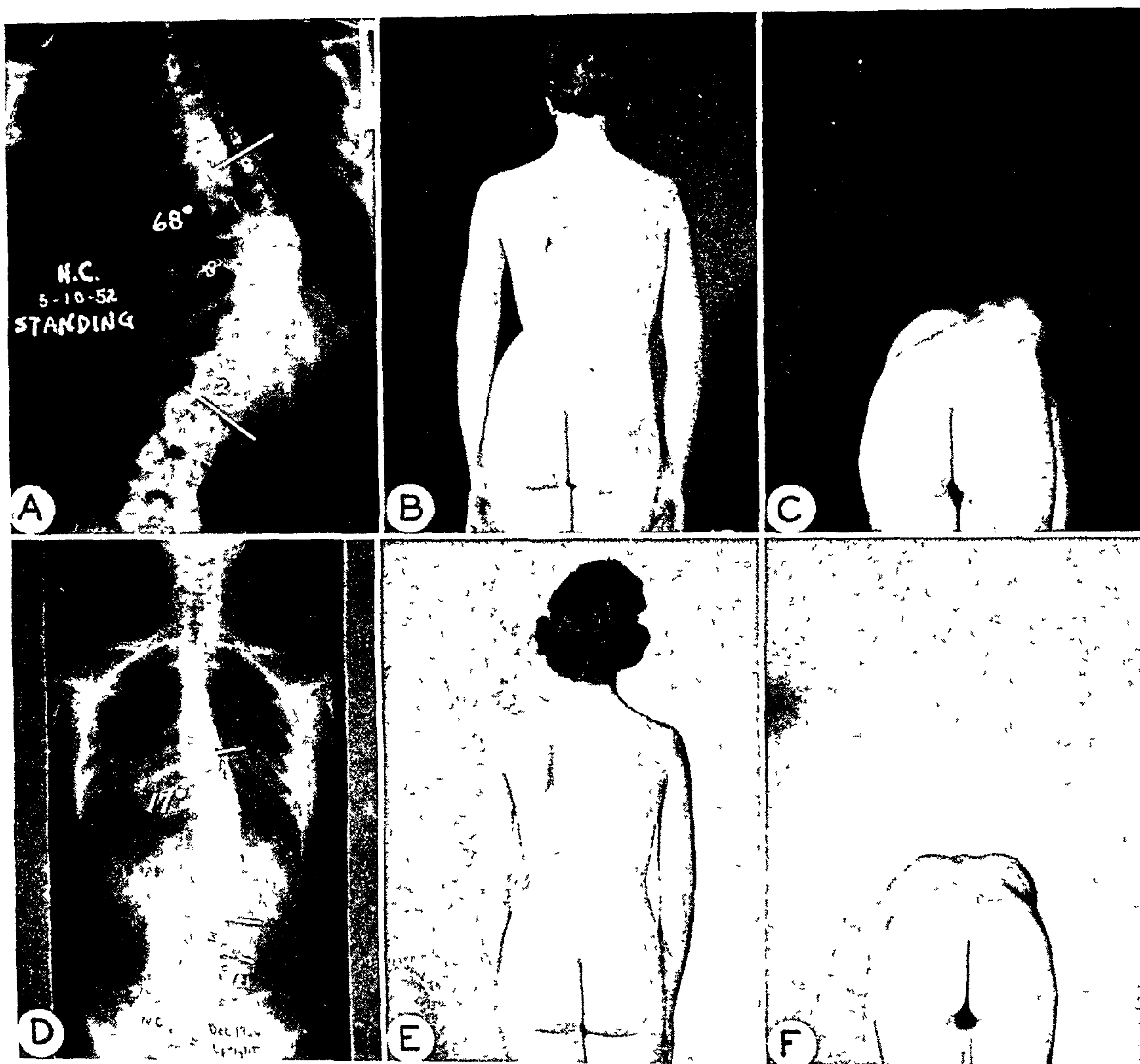


Fig 16 *Case N C* Idiopathic Scoliosis Thoracolumbar Curve Age at operation — sixteen years Supplementary bone used — fresh autogenous ilium
A,B,C—Preoperative.
D,E,F—Four years and six months postoperative

Case K H. (Fig 17) This patient was handled in the same fashion as patient *N C* The patient and parents made the final decision for operation

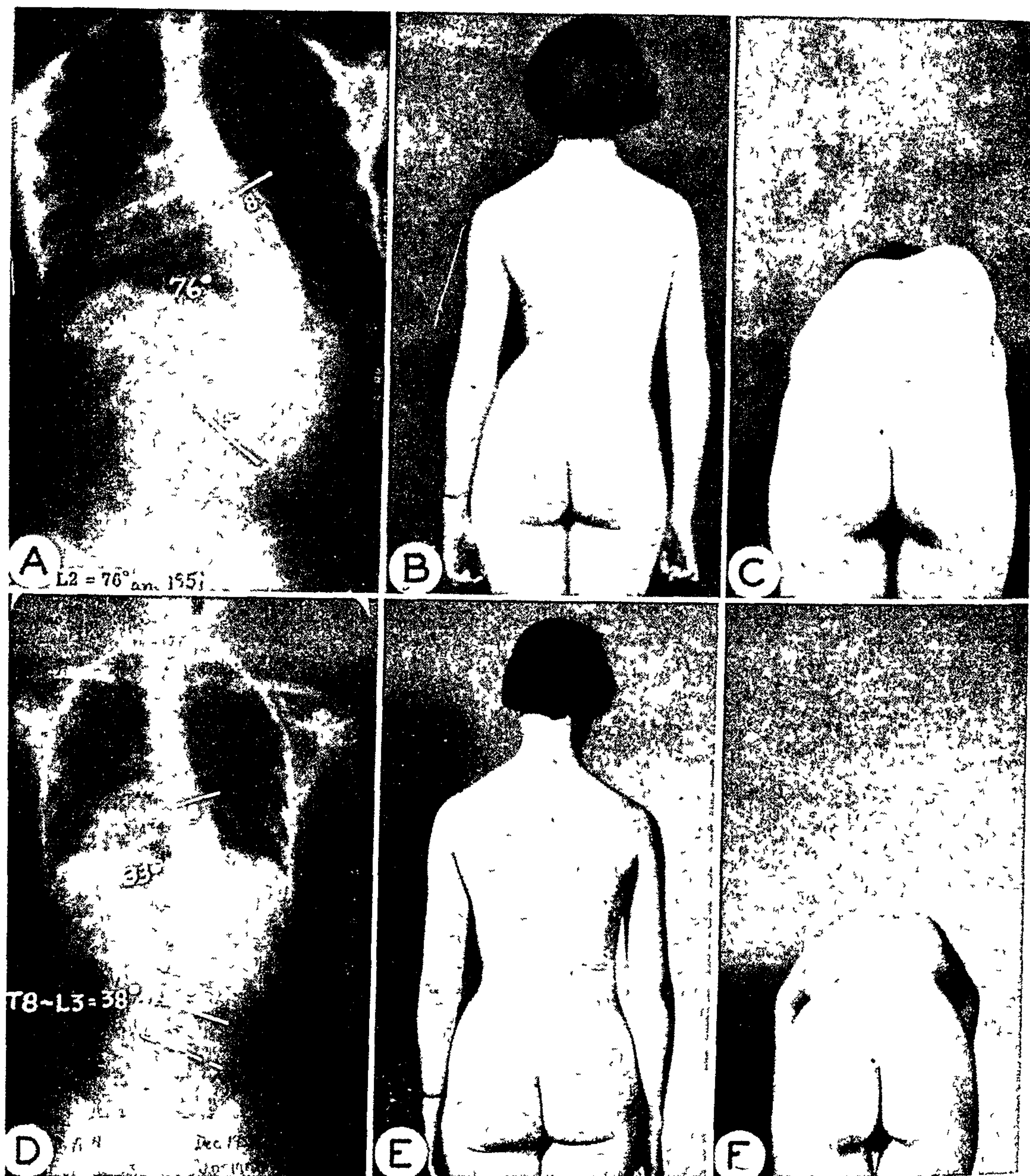


Fig 17 *Case K H.* IDIOPATHIC SCOLIOSIS THORACOLUMBAR CURVE Age at operation — fourteen years Supplementary bone used — banked bone chips
A,B,C—Preoperative
D,E,F—Five years and nine months postoperative

TABLE IV

IDIOPATHIC SCOLIOSIS—MAIN LUMBAR AND THORACOLUMBAR CURVES

Case	*Curve* Pattern*	*Precorrection Curve*	*Pre-op Corrected Curve*	*Extent of Fusion*	*Final Curve (Primary)*	*Follow-up (yr + mo)*	*Per Cent Pre-op Correction*	*Per Cent Loss of Correction*	*Age at Operation (yr + mo)*	*Months Recumbent*	*Type of Graft‡*	*Status of Fusion*
L P	ML	**52°**	**7°**	(T10-L4)†	**17°**	10+6	**86**	**22**	13+2	*5*	OP	solid
M J	TL	**42°**	**16°**	(T9-L3) +1†	**40°**	15+3	**62**	**92**	26	*4*	OP	solid
K H.	TL	**76°**	**17°**	(T8-L2)	**33°**	5+9	**78**	**27**	14	*8*	BB	solid
N C.	TL	**68°**	**16°**	(T7-L2)	**17°**	4+6	**76**	**2**	16	*8*	AI	solid
R M	TL	**95°**	**31°**	(T7-L2)	**88°**	4+0	**67**	**89**	13+1	*9*	BB	pseud.

*ML = main lumbar curve TL = thoracolumbar curve

†Primary curve is in parenthesis, number outside parenthesis indicates additional vertebra (distal) included in the fusion.

‡OP = osteoperiosteal graft supplement BB = banked homogenous bone supplement AI = fresh autogenous ilium supplement

Main Thoracic Curve

As Ponseti (1950) pointed out, the thoracic curve progresses more rapidly and produces a greater deformity than the other curve patterns in idiopathic scoliosis. Fixed, irreversible deformity may develop relatively early in the evolution of this curve pattern. The patients in this category, especially those with onset under ten years of age (juvenile and infantile types) offer some of the more difficult problems in the surgical treatment of scoliosis.

In the adolescent type of main thoracic curve, with onset at older age, in whom operation can be postponed to or near bone maturity without losing significant correctibility, the results of surgical treatment are uniformly successful when optimum correction is obtained, the fusion is placed properly, and a massive solid graft is obtained (*Case M. V*, Fig. 18; *Case D. St.*, Fig. 19; *Case A. S.*, Fig. 20).

On the other hand, in the patient who shows a rapidly progressive curve, and undergoes surgical treatment at an early age — several years prior to bone maturity — the result of surgical treatment, even with the above criteria fulfilled, is less certain than in the adolescent patient. With continued growth, further changes occur in the spine above and below the fused corrected curve. These changes alter the final clinical result (*Case S. Ry.*, Fig. 23; *Case J. M.*, Fig. 24; *Case L. M.*, Fig. 25; *Case D. H.*, Fig. 26). Despite this fact, certain rapidly progressing thoracic curvatures require operation at an early age to prevent a severe rigid deformity (*Case P. W.*, Fig. 28).

There were twenty-six patients in this category including the one curvature associated with neurofibromatosis (*Case S. Ry.*). The follow-up of five patients was too brief for evaluation. An analysis of the other twenty-one cases follows (Table V). In seven cases, the primary curve alone was fused. Nine patients had the primary curve plus one vertebra above, and three patients the primary curve plus one vertebra above and below, included in the fusion. In two children, with severe curvatures, the fusions were extended to include parallel vertebrae; in one, the primary curve plus one vertebra above and two below, and in the other, the primary curve plus two vertebrae above and three below were included in the fusion.

Fig. 18 *Case M V* IDIOPATHIC SCOLIOSIS MAIN THORACIC CURVE, ADOLESCENT TYPE
Age at operation — fifteen years and four months Supplementary bone used — osteoperiosteal graft
A,B—Preoperative
C,D—Seventeen years and eight months postoperative Friedreich's ataxia has developed

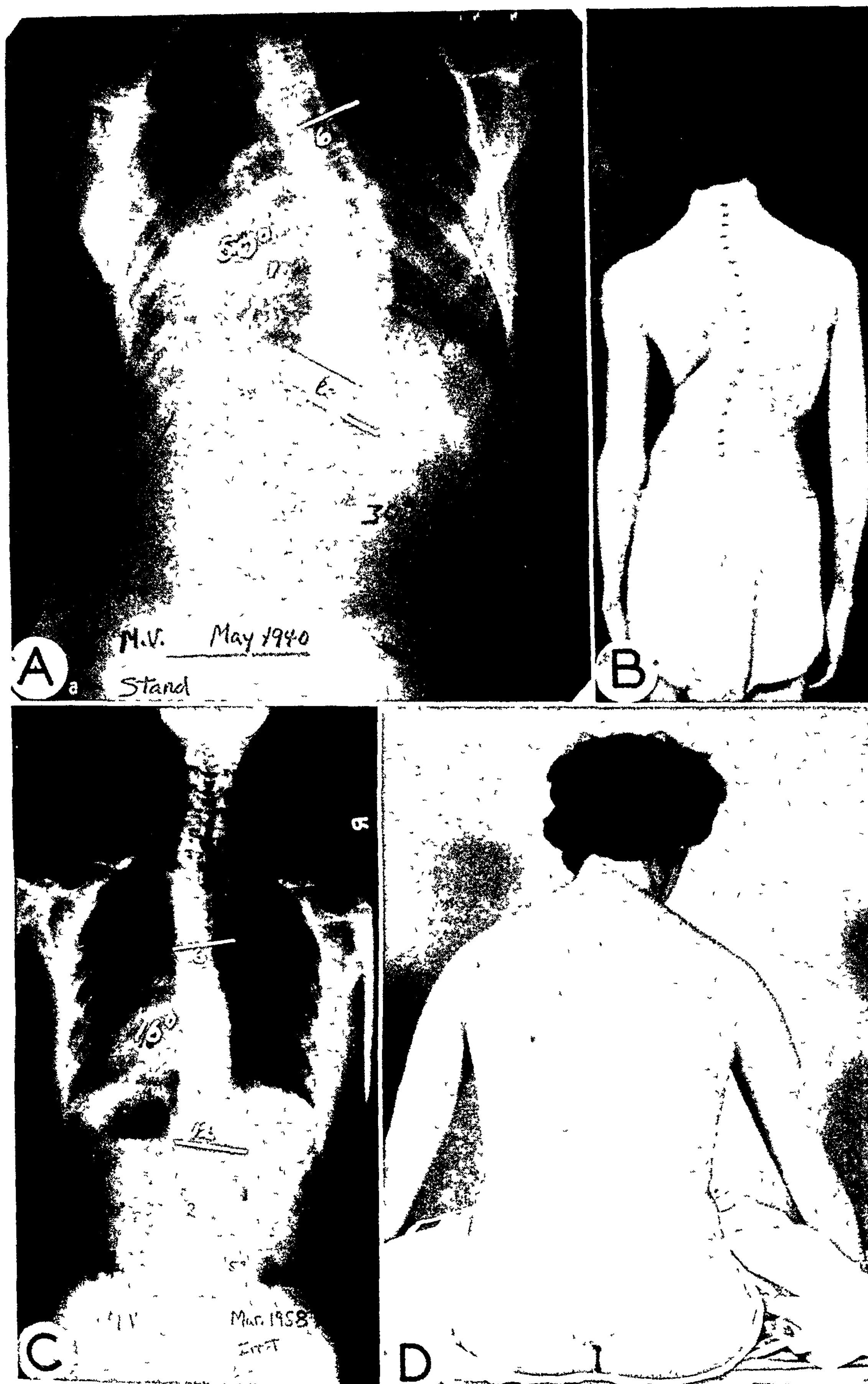


Fig 18 *(Legend on facing page)*

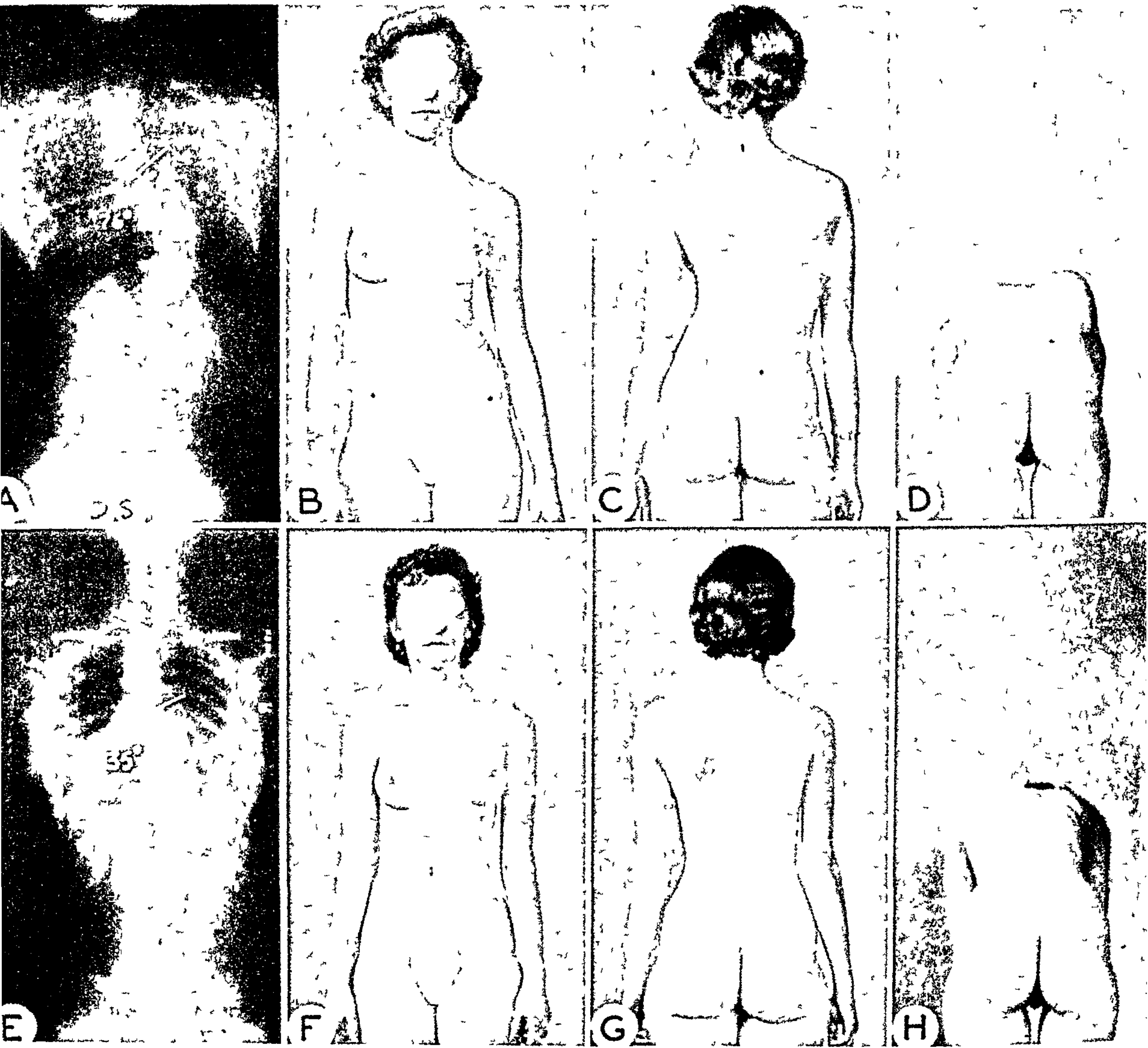


Fig 19 *Case D St* Idiopathic Scoliosis Main Thoracic Curve, Adolescent Type
Age at operation — thirteen years and six months Supplementary bone used — fresh autogenous ilium

A,B,C,D—Preoperative

E,F,G,H—Three years postoperative

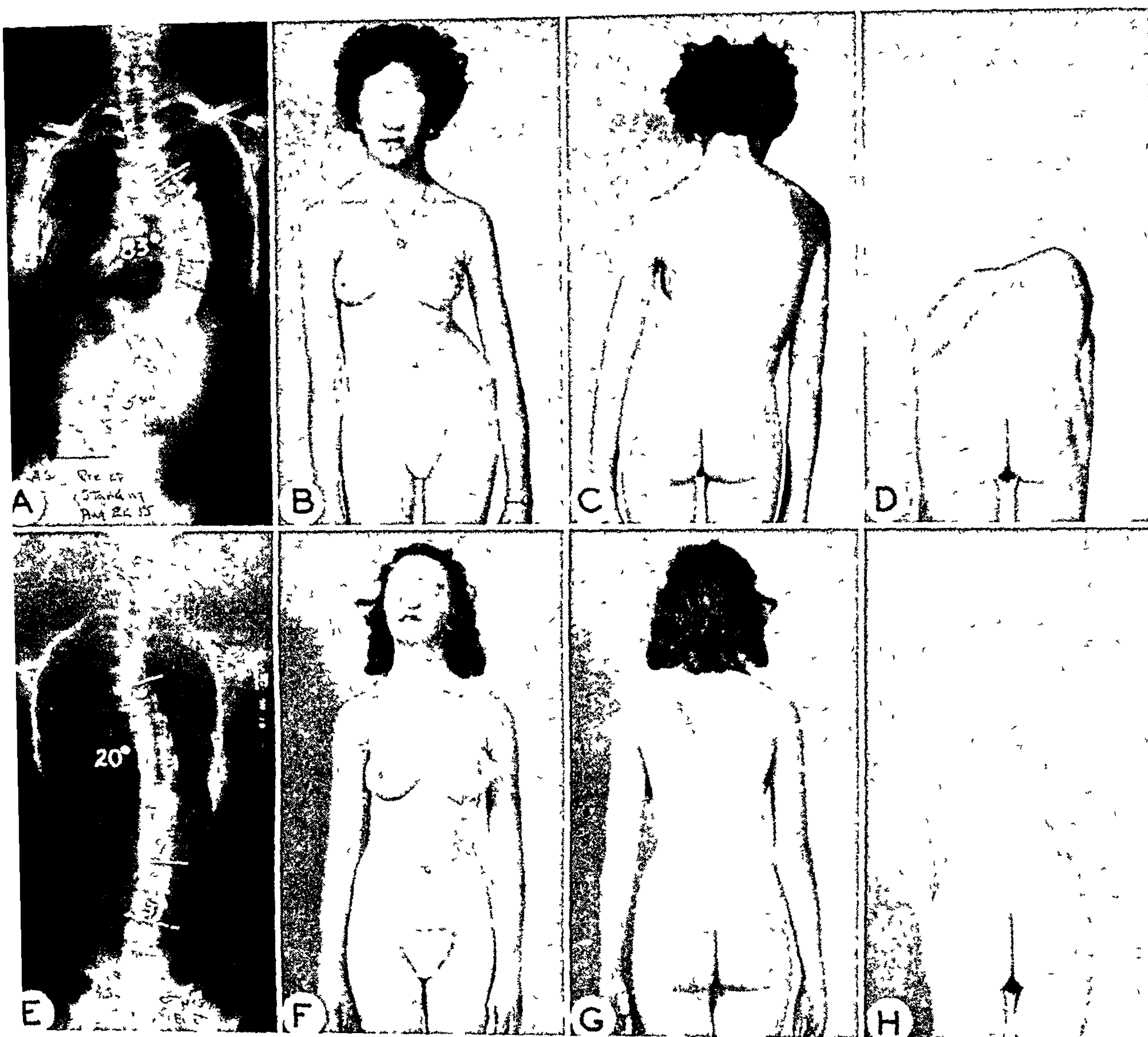


Fig 20 *Case A S.* IDIOPATHIC SCOLIOSIS MAIN THORACIC CURVE, ADOLESCENT TYPE. Age at operation — twelve years and five months Supplementary bone used — fresh autogenous ilium

A,B,C,D—Preoperative

E,F,G,H—Two years postoperative General physical development and ossification of iliac apophysis is indicative of completion of spinal growth (Last examination at two years and six months postoperative shows no change T6-L1=20°.)

TABLE V

IDIOPATHIC SCOLIOSIS—

Case	*Precorrection Curve*	*Pre-op Corrected Curve*	*Extent of Fusion*	*Final Curve (Primary)*	*Follow up (yr + mo)*
M.V.	50°	8°	1+(T6-12)	16°	17+8
A.H.	45°	3°	1+(T6-12)	0°	4+9
J B	87°	25°	1+(T6-L1)	56°	9+0
D H	58°	5°	1+(T6-12)+1	12°	6+0
J M	110°	52°	1+(T4-12)+2	50°	6+0
P W	148°	85°	2+(T5-12)+3	98°	5+8
D.G	67°	20°	(T5-12)	30°	4+5
S Ry	71°	34°	1+(T7-11)	38°	4+0
D St.	76°	29°	1+(T6-12)+1	35°	3+0
D R	87°	40°	1+(T5-11)	52°	3+3
A Hag	74°	15°	1+(T6-12)	20°	3+0
L.M.	90°	42°	1+(T6-L1)	47°	2+11
S L	70°	16°	1+(T6-L1)	30°	2+9
D Sey.	75°	33°	(T6-L1)	56°	1+6
T He.	87°	27°	(T5-12)	37°	2+6
A S.	83°	17°	1+(T6-L1)	20°	2+6
A L.	90°	30°	(T4-12)	38°	2+4
J W	87°	46°	(T6-12)	45°	2+0
C Tin	80°	41°	1+(T5-11)+1	43°	2+0
R H	82°	43°	(T5-12)	44°	2+0
B.C	73°	18°	(T5-12)	23°	1+6

*Primary curve is in parenthesis, numbers outside parenthesis indicate additional vertebrae, proximal (left) and distal (right), included in the fusion

†OP = osteoperiosteal graft supplement BB = banked homogenous bone supplement AI = fresh autogenous ilium supplement

TABLE V

MAIN THORACIC CURVE

Per cent Pre-op Correction	*Per cent Loss of Correction*	*Age at Operation (yr + mo)*	*Months Recumbent*	*Type of Graft†*	*Status of Fusion*
84	19	15+4	4	OP	solid
93	0	8+11	4	OP	solid
71	50	17+0	5	OP	pseud.
91	13	11+6	4	OP	solid
53	0	12+11	9	OP+BB	solid
42	21	14+7	9	AI+BB	solid
70	21	13+0	9½	AI	solid
52	11	12+10	8	AI	solid
67	15	13+6	9½	AI	solid
54	25	14+9	8½	AI	solid
80	8	13+0	8	AI	solid
53	10	13+5	8	AI	solid
77	26	14+10	6½	AI	pseud healed
56	55	15+3	6	AI	solid
69	17	13+11	6	AI	solid
79	4	12+5	6	AI	solid
67	13	11+6	6	AI	solid
47	0	12+8	8	AI	solid
49	5	16+4	6	AI	solid
47	2	14+7	8	AI	solid
75	9	13+11	8	AI	solid

Two pseudarthroses occurred in this group, as follows:

In *Case J B* (Fig 21) an 87-degree curvature was corrected to 25 degrees and lost correction to 56 degrees The fusion which included the primary curve plus one vertebra above was supplemented with an osteoperiosteal graft Although a significant loss in correction occurred because of the pseudarthrosis, the trunk is better balanced than it was preoperatively.

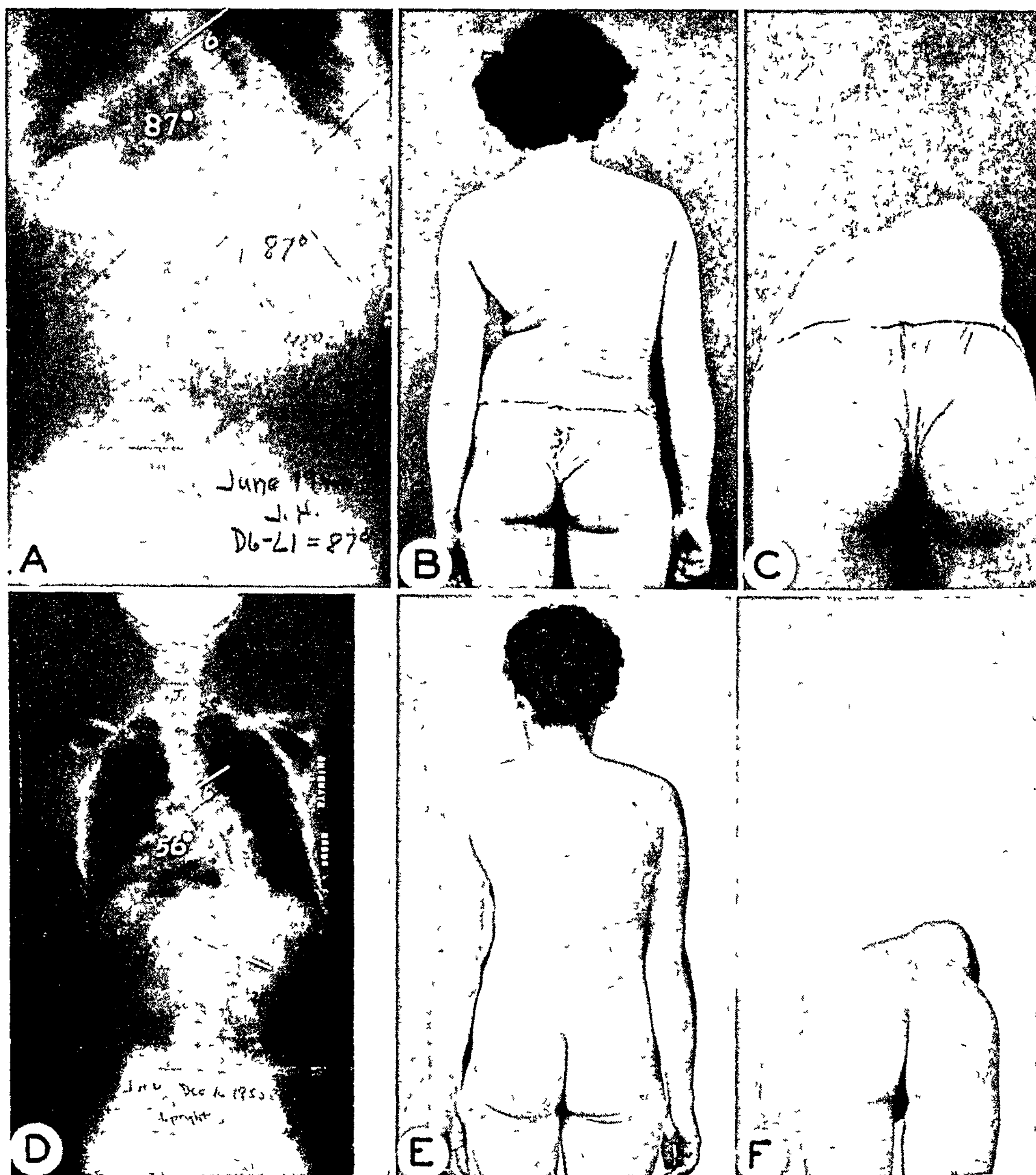


Fig 21 *Case J B*. IDIOPATHIC SCOLIOSIS MAIN THORACIC CURVE, ADOLESCENT TYPE Age at operation — seventeen years Supplementary bone used — osteoperiosteal graft

A,B,C—Preoperative

D,E,F—Nine years postoperative A pseudarthrosis developed with significant loss in correction but some clinical improvement was retained

The second pseudarthrosis occurred in *Case S L* (Fig. 22) A 70-degree curvature was corrected to 16 degrees. The fusion, which was supplemented with fresh autogenous iliac bone, included the primary curve plus one vertebra above A pseudarthrosis at the last joint in the fusion area was noted in the routine oblique view of the spine taken at eleven months after operation At the same time some loss of correction was observed in the anteroposterior roentgenogram The curve measured 16 degrees at the time of removal of the turnbuckle plaster cast, the angular value was 30 degrees at one year after operation, and the same at two years after operation Several patients in this series were ambulant six months after operation. After observing the results in two patients—*Case D Sey* (Table III and *Case S L*, Fig 22—ambulant after six months, the routine of eight months in recumbency was again adopted

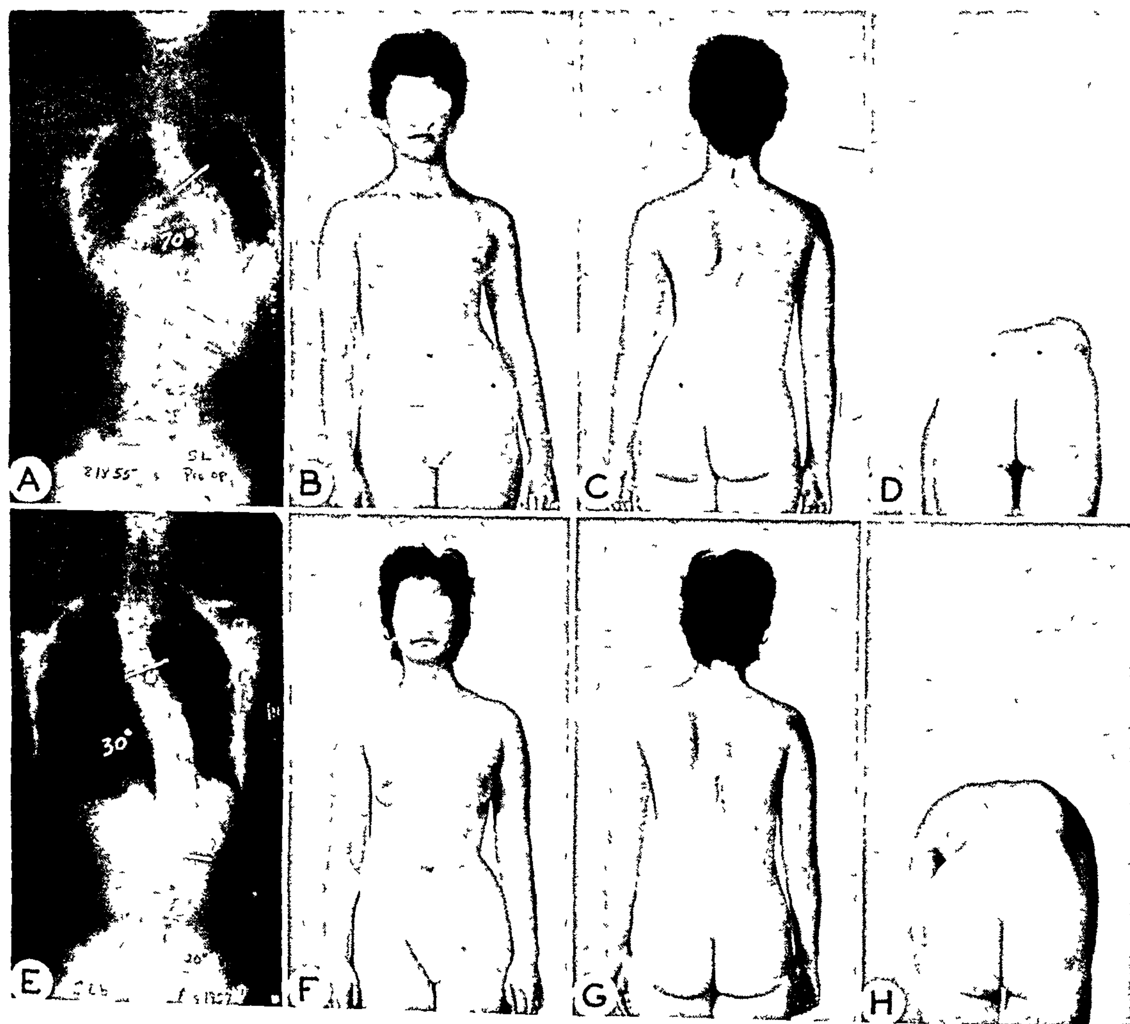


Fig 22 *Case S L* IDIOPATHIC SCOLIOSIS: MAIN THORACIC CURVE, ADOLESCENT TYPE Age at operation — fourteen years and ten months Supplementary bone used — fresh autogenous ilium

A,B,C,D—Preoperative

E,F,G,H—Two years postoperative A pseudarthrosis which developed at the last joint in the fusion area healed spontaneously with 14 degrees loss of correction

As stated earlier, skeletal development and therefore spinal growth is nearing completion at the age of thirteen and one-half years to fourteen years in girls and about one year later in boys. Surgical treatment for scoliosis instituted at about this age is considered free from the uncertainties of treatment at an earlier age, because the unpredictable changes in the spine occurring with continued spinal growth no longer prevail.

The chronological age, however, is only one of the criteria for determining the most desirable age for fusion of the scoliotic spine. The bone age, the status of the ossification of the iliac apophysis, the onset of menses, and the state of development of the physical characteristics of puberty are also valuable indices. All these data should be considered in arriving at a decision in those patients in whom delay is permissible.

Illustrative Cases — Main Thoracic Curve

Two examples are included to point out the wide variation that may occur between the chronological age and skeletal development in different patients

Case A S (Fig 20) Although this patient was only twelve years and five months old at the time of operation, she showed early ossification in the iliac apophysis and well-developed physical characteristics — evidence of approaching bone maturity and completion of spinal growth Two years after operation, the fusion is solid and the correction has held Roentgenograms show distal extension of the primary curve to include the second and third lumbar vertebrae (Fig 20 E) However, this alteration of the primary curve did not significantly influence the final clinical deformity, because surgery was performed at puberty when spinal growth is virtually completed

Case S. Ry (Fig. 23) was operated on at twelve years and ten months of age, but there was no evidence of ossification in the iliac apophysis and her physical development was far behind that of *Case A S* After surgical treatment, satisfactory correction of the fused primary curve was retained, but the curve extended to include two distal vertebrae The primary curve, thoracic seven to eleven, measured 38 degrees and the extended postoperative curve, thoracic seven to lumbar one, measured 55 degrees This has resulted in recurrence of a significant degree of deformity This might not have occurred if fusion had been extended to the second lumbar vertebra. Although the curve was progressing, a further period of observation to more nearly approximate bone maturity at surgery would have been preferable This patient has café-au-lait skin lesions with no other evidences of neurofibromatosis

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Fig 23 *Case S Ry* Idiopathic Scoliosis Main Thoracic Curve, Adolescent Type (Neurofibromatosis). Age at operation — twelve years and ten months Supplementary bone used — fresh autogenous ilium
A,B,C—Preoperative
D,E,F—Seventeen months postoperative
G,H,I—Three years and six months postoperative.
The iliac apophysis, at the time of operation, showed no ossification and the child was generally underdeveloped.

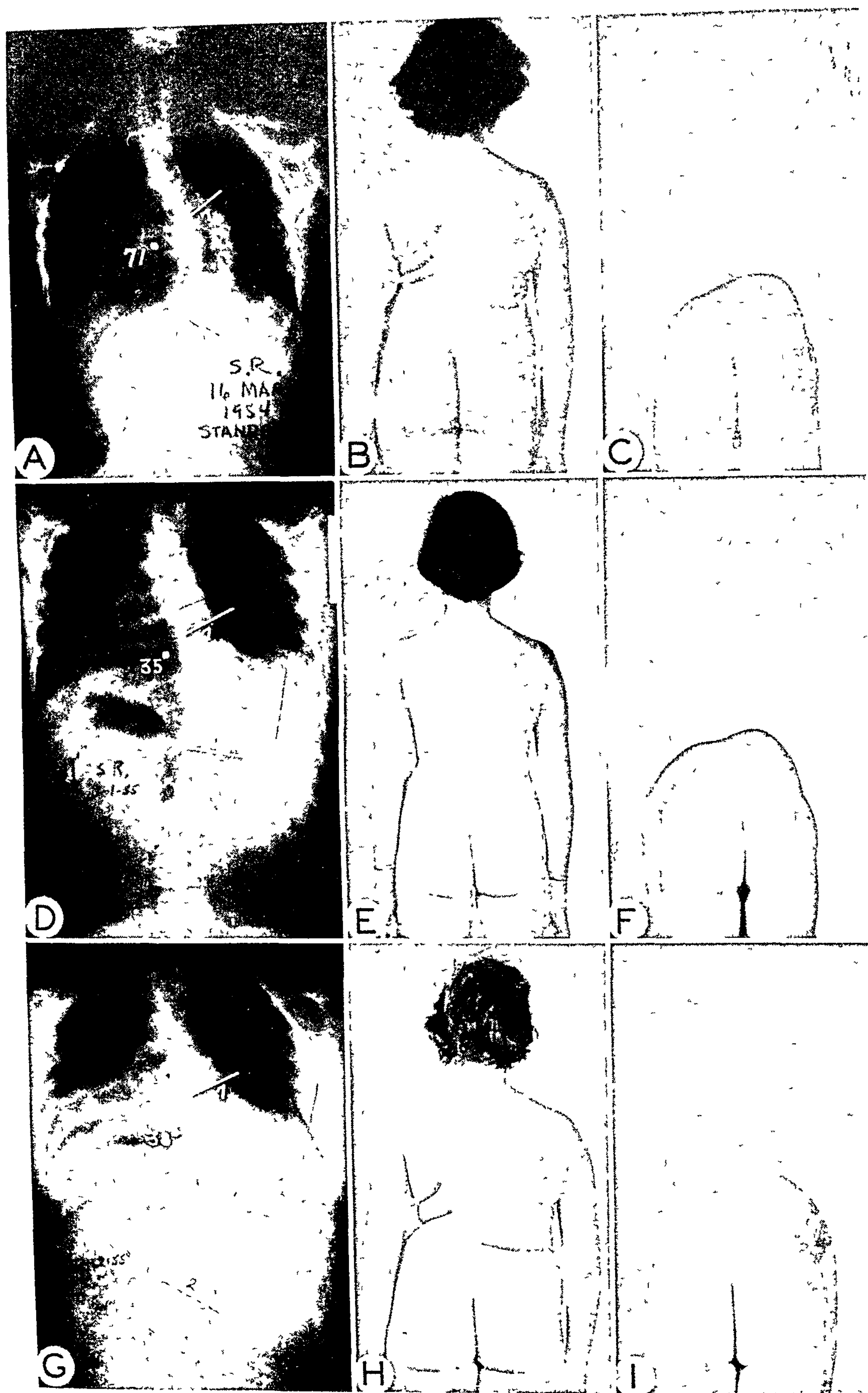


Fig 23 *(Legend on facing page)*

Case J. M. (Fig 24) and *Case L M.* (Fig 25) illustrate the same point, namely, distal extension of the primary curve postoperatively. *Case J. M* had a long fusion including one vertebra above and two below Despite this, the primary curve extended to include two vertebrae beyond the distal end of the fusion (the third and fourth lumbar vertebrae), and resulted in the same long rotational deformity seen in *Case L M.* who had a short fusion ending at the bottom vertebra in the primary curve These two cases had strikingly similar right thoracic curve patterns which progressed rapidly and showed early asymmetrical development of three vertebrae at the apex of the curvature. Neither patient showed clinical evidence of neurofibromatosis In *Case J. M* signs of primary lower motor neuron disease developed *Case J. M* and *Case S. Ry* are included in this section because the problem in treatment was that of the progressive Main Thoracic Curve Pattern.

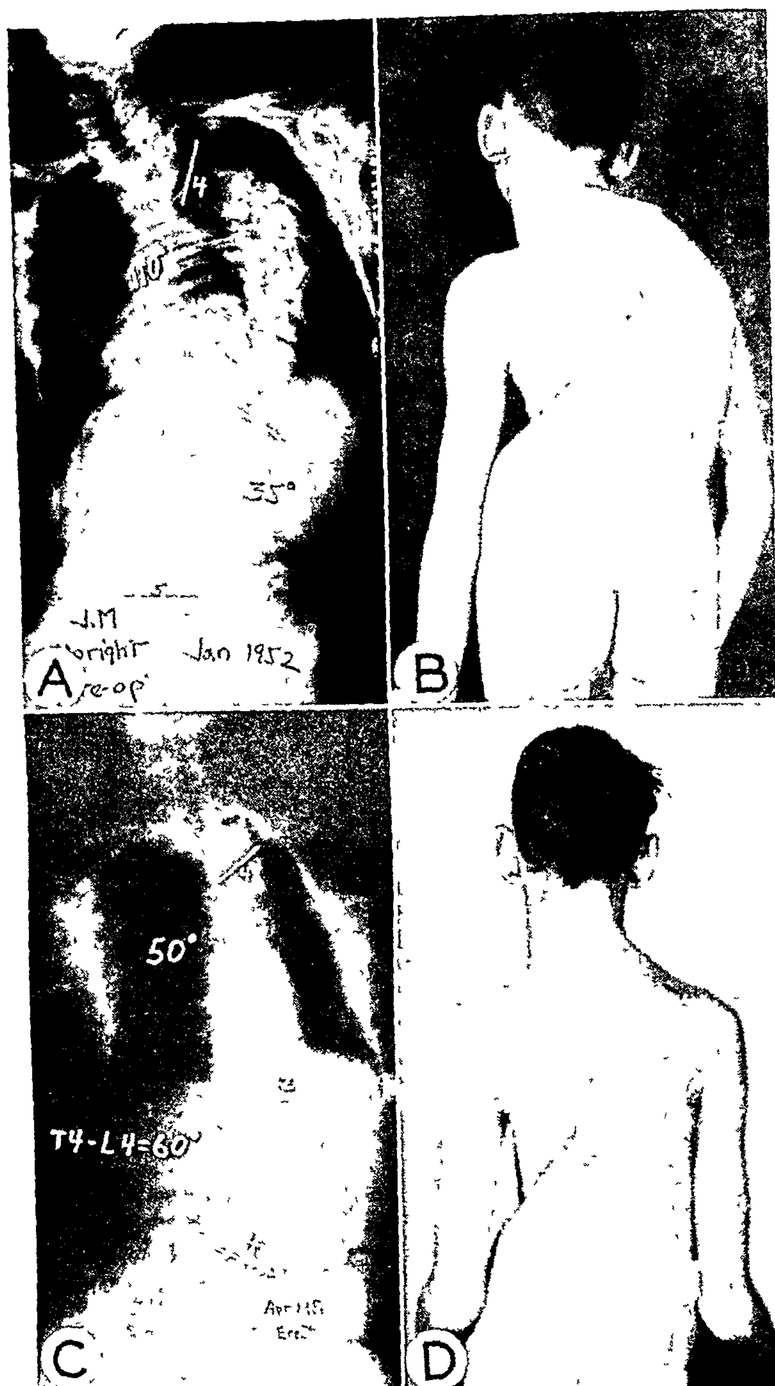


Fig 24 *Case J M* Idiopathic Scoliosis Main Thoracic Curve, Juvenile Type Age at operation — twelve years and eleven months Supplementary bone used — banked bone chips

A,B—Preoperative

C,D—Five years and four months postoperative.

The fusion in this case was extended to include one vertebra above and two below the primary curve Despite a long fusion, the curve extended to incorporate the third and fourth lumbar vertebrae Postoperative course was complicated by the development of primary lower motor neuron disease, pelvic obliquity and hip flexion deformities

Fig 25. *Case L M* Idiopathic Scoliosis Main Thoracic Curve, Juvenile Type Age at operation — thirteen years and five months Supplementary bone used — fresh autogenous ilium

A,B,C—Preoperative
D —Seven months postoperative
E,F —Eleven months postoperative
G,H,I—Two years and eleven months postoperative showing extension of the primary curve in the roentgenogram Correction in the fused area, the primary curve, was maintained at 47 degrees but the extended curve including the sixth thoracic to the fourth lumbar vertebrae measures 87 degrees, the latter is representative of the actual clinical deformity The fusion should have been extended to include the third lumbar vertebra

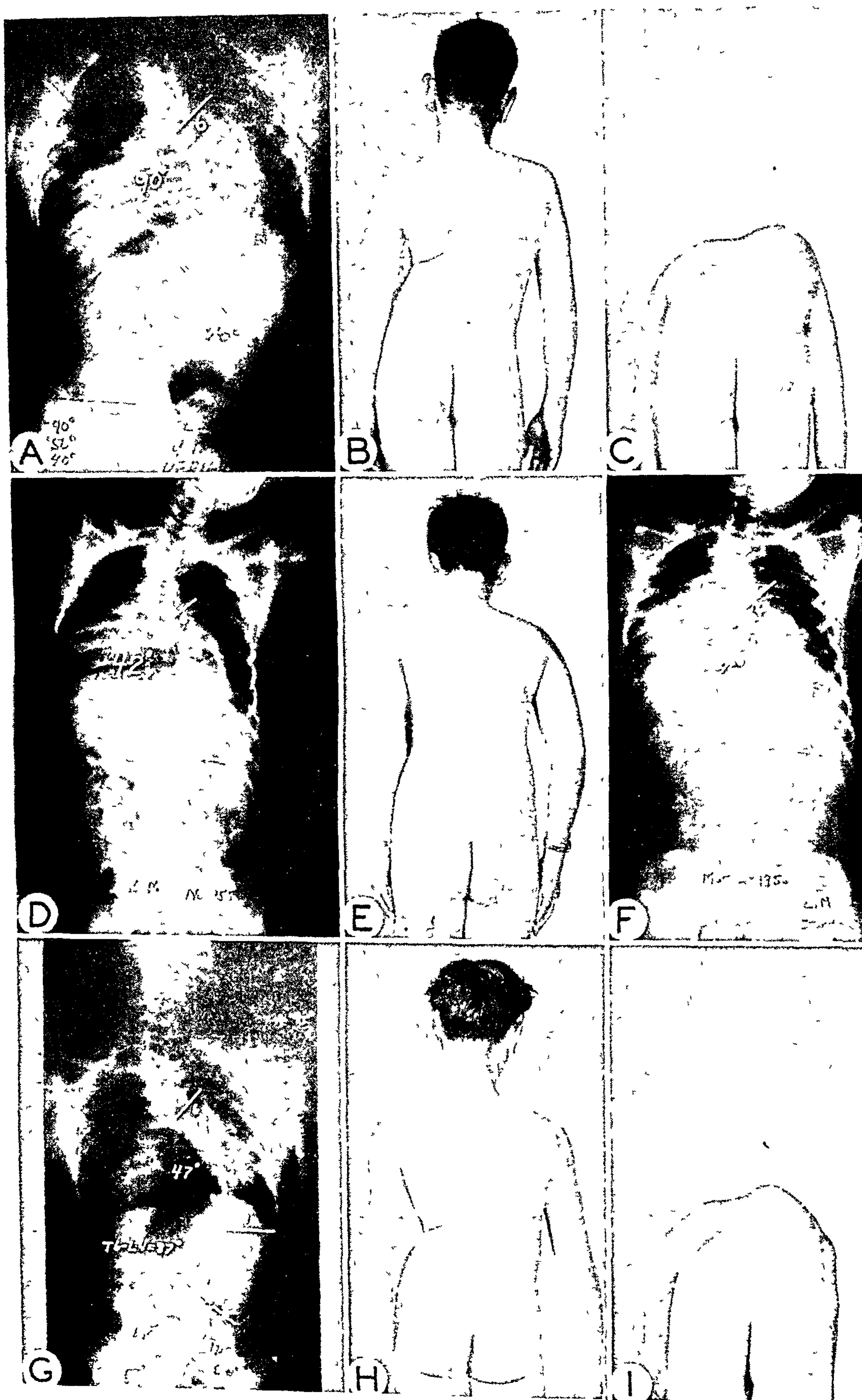


Fig 25 *(Legend on facing page)*

Case D H (Fig. 26) was operated on at the age of eleven years and six months. A very mobile curve of 58 degrees was corrected to 5 degrees, and correction was retained at 12 degrees Postoperatively, the primary curve extended distally to include the second, third, and fourth lumbar vertebrae The residual clinical deformity is represented, therefore, by a long thoracolumbar curve extending from thoracic six to lumbar four and measures 31 degrees (Fig 26 C) Such a curvature now is not operated on at this stage but is followed to as near bone maturity as possible depending upon the progress and characteristics of the deformity. Palliative corrective measures discussed on page 69 aid in this delaying action



Fig 26 *Case D H* Idiopathic Scoliosis Main Thoracic Curve, Juvenile Type
Age at operation — eleven years and six months — small underdeveloped child Supplementary bone used — osteoperiosteal graft

A—Preoperative
B—Six months postoperative at time of removal of Risser cast.
C—Three years postoperative, showing extension of the primary curve to include three vertebra beyond the fusion extending down to the fourth lumbar vertebra with maintenance of correction in the fused area The fusion in this case included one vertebra above and one below the primary curve.

Case A H (Fig 27) demonstrates the development of an increasing lordotic deformity when the thoracic spine is fused at an early age In this patient fusion was performed at eight years and eleven months, the youngest patient operated on in this series.

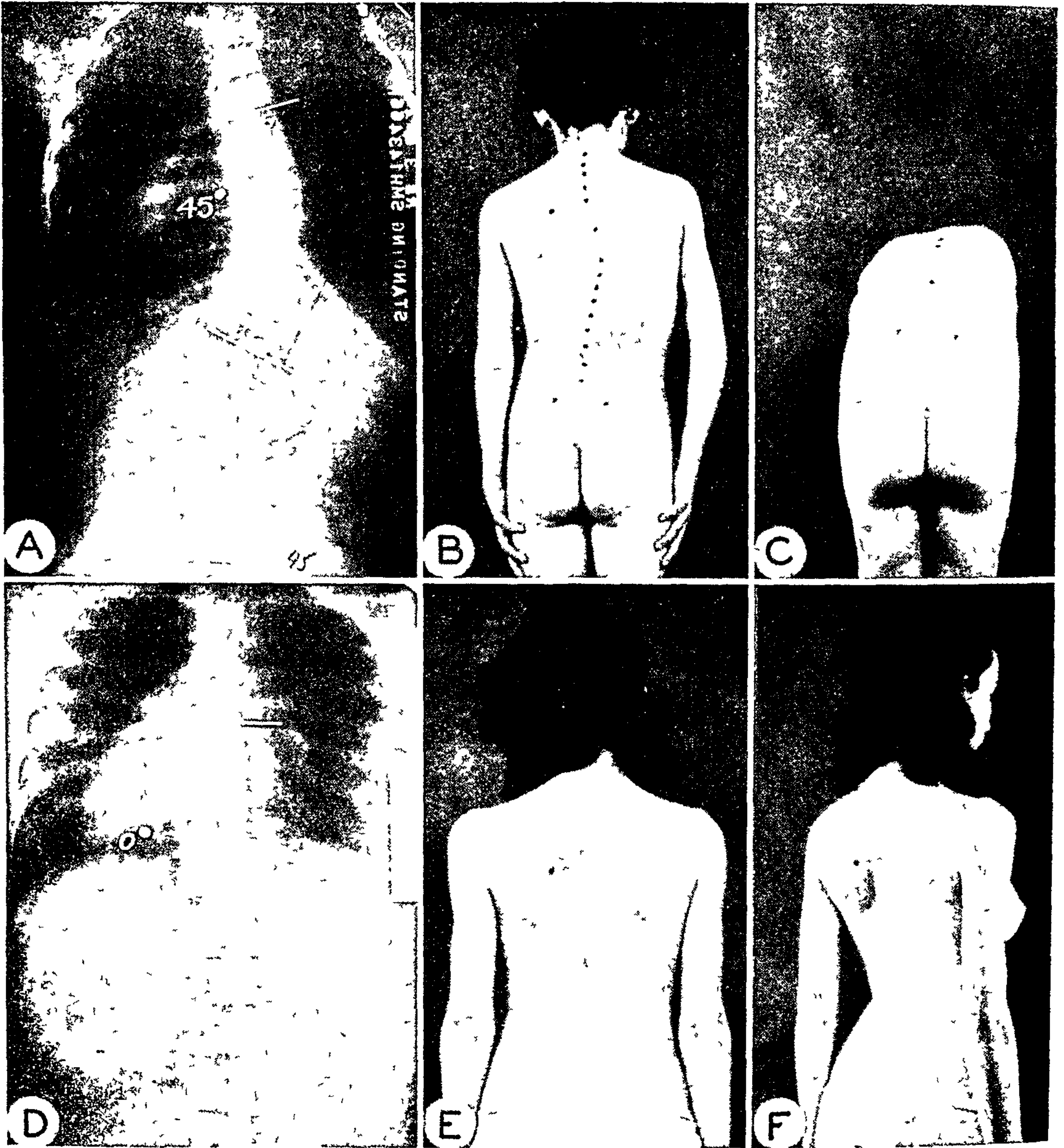


Fig 27 *Case A H* IDIOPATHIC SCOLIOSIS MAIN THORACIC CURVE, JUVENILE TYPE. Age at operation — eight years and eleven months Supplementary bone used — osteoperiosteal graft

A,B,C—Preoperative

D,E,F—Four years and nine months postoperative at the age of thirteen years and eight months Note a moderately severe lordosis extending from the upper thoracic spine to the sacrum due to fusion at an early age

(From *Medical Clinics of North America*[9], Courtesy, W. B. Saunders Co., Philadelphia, Pennsylvania)

Case P. W (Fig 28) represents a neglected juvenile thoracic curve with a very severe rigid deformity The thoracic curve of 148 degrees was corrected to 85 degrees and a long fusion was performed between parallel lines including two vertebrae above and two below the primary curve Correction has been maintained at 98 degrees with a very satisfactory clinical result for this type of deformity.

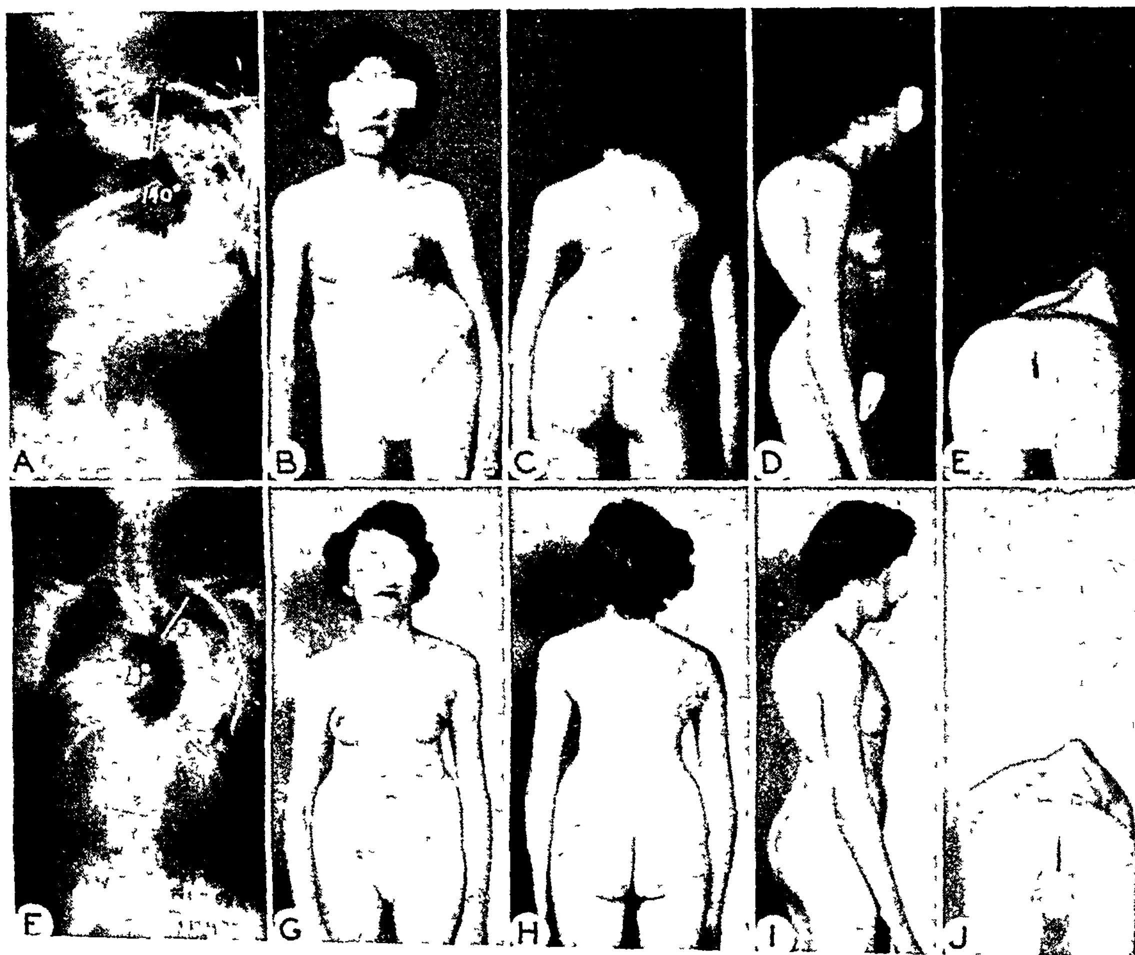


Fig 28 *Case P W* IDIOPATHIC SCOLIOSIS. MAIN THORACIC CURVE, JUVENILE TYPE Age at operation — fourteen years and seven months Supplementary bone used — fresh autogenous ilium at stage one and banked bone chips at stage two

A,B,C,D,E—Preoperative.

F,G,H,I,J —Five years and eight months postoperative showing satisfactory correction of a severe rigid type of curve The razor-back thoracic rotational deformity cannot be corrected in such cases Improvement, however, is significant and surgical treatment is worthwhile.

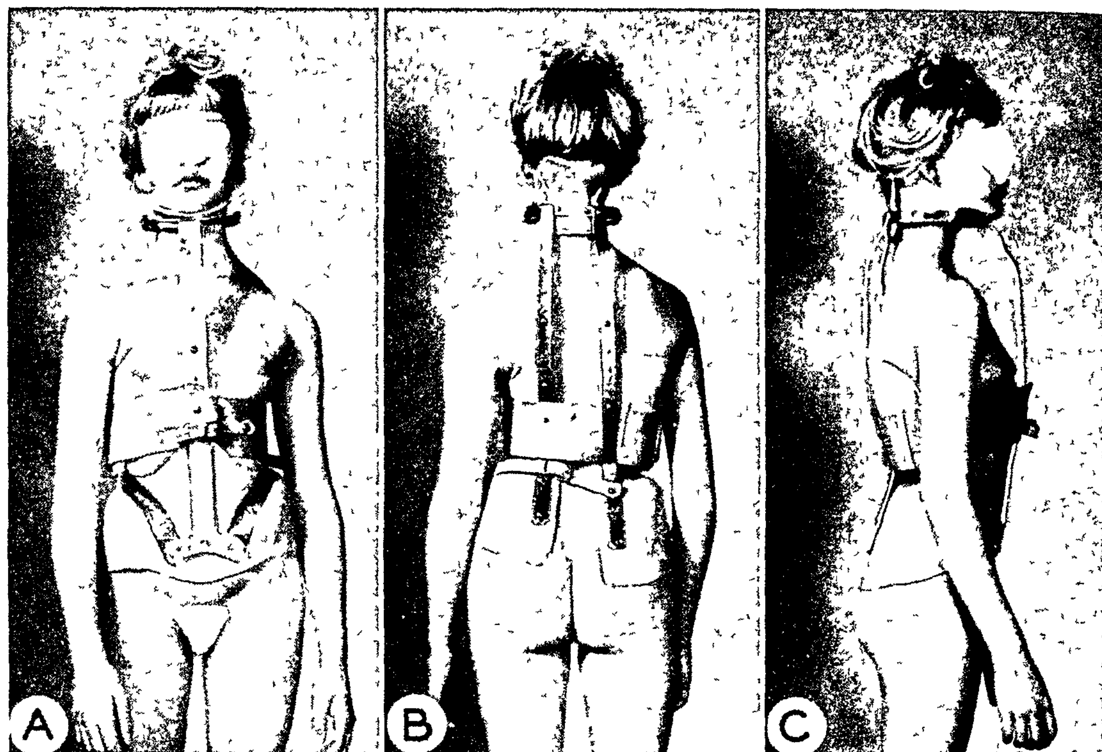


Fig 30. Milwaukee Brace

Fig 31 Determining Degree of Fixed Deformity with Lateral Bend Roentgenogram

A—Right thoracolumbar curve

B—Lateral bend roentgenogram shows 25 degrees fixed angulation

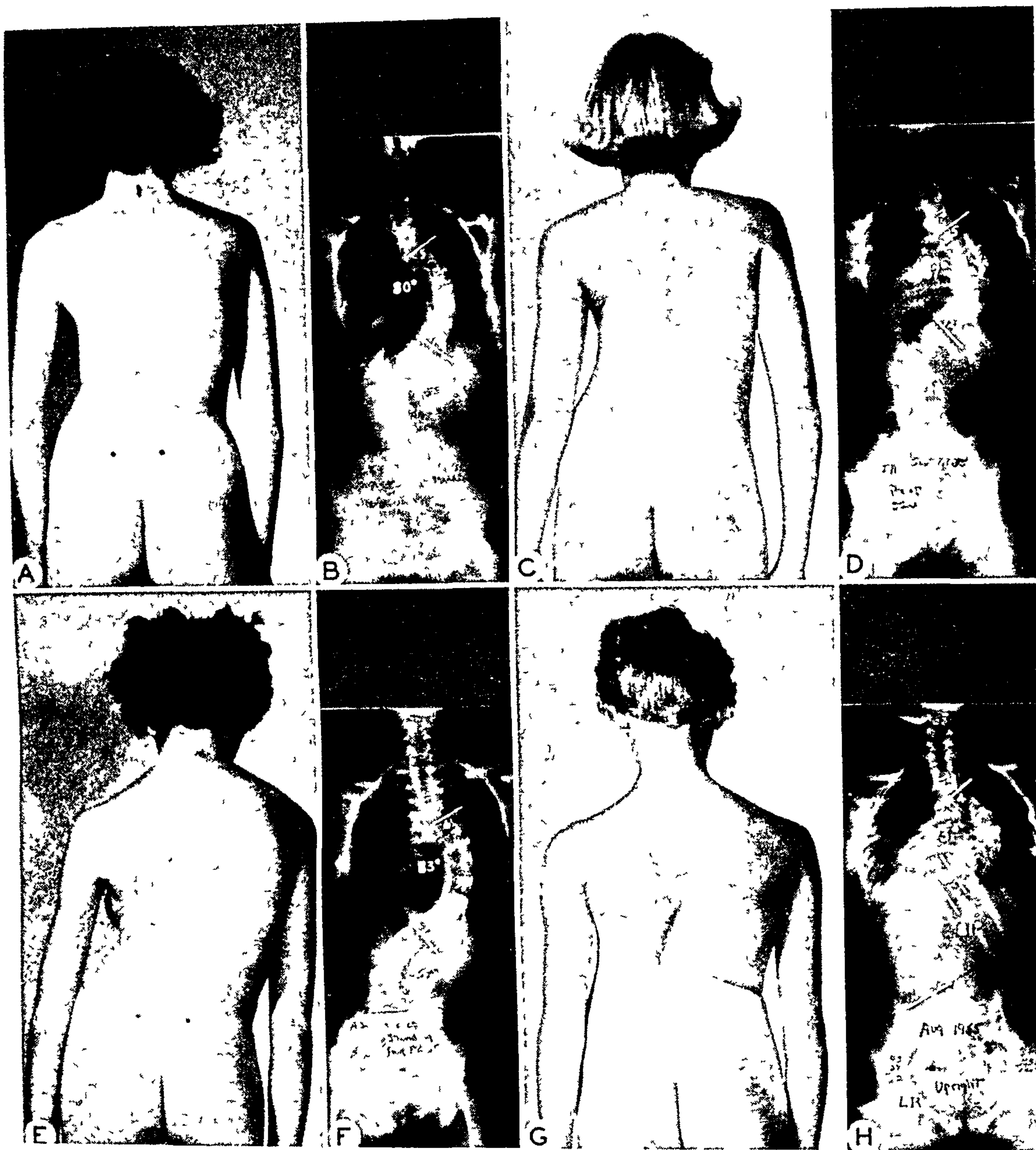


Fig 32 VARIATION IN THE CLINICAL DEFORMITY IN RELATION TO CURVATURES OF APPROXIMATELY EQUAL ANGULATION.

A,B,C,D,E,F—Clinical photographs and roentgenograms of three patients with a MAIN THORACIC CURVE

G,H —Clinical photograph and roentgenogram of a patient with a COMBINED THORACIC AND LUMBAR CURVE

Illustrative Cases — Combined Thoracic and Lumbar Curve

Case P. Cam (Fig 33) was operated on at twelve years and eleven months of age A right thoracic curve measuring 40 degrees in August 1950, increased to 108 degrees by April 1952. Lateral bend roentgenograms showed an angular deformity to the left totalling 86 degrees. The right thoracic curve (T6-12) was corrected preoperatively to 57 degrees so that there was a significant degree of over-correction The fusion extending from the fifth to the eleventh thoracic vertebrae excluded the bottom vertebra in the primary curve Although not intentional, it was, however, fortunate The final angular value in the right thoracic curve was 85 degrees The corrected *fused portion* of the primary curve (T6-11), preoperatively, measured 60 degrees and the final value was 70 degrees The primary curve extended postoperativly to include L1 Fifteen-degree angulation occurred at T11-12 and T12-L1. The end result is a well-balanced trunk with maintenance of very satisfactory correction This curve had increased rapidly during the year prior to operation and, although it is impossible to say that such progress would have continued, it is reasonable to assume that the patient benefited by the procedure. I think from the standpoint of both cosmetics and function, surgical treatment in this type of situation is worthwhile Measurement of all the curves in the spine in this case at five years postoperatively at the age of eighteen years gives a value of 99 degrees angular deformity to the right and 101 degrees to the left

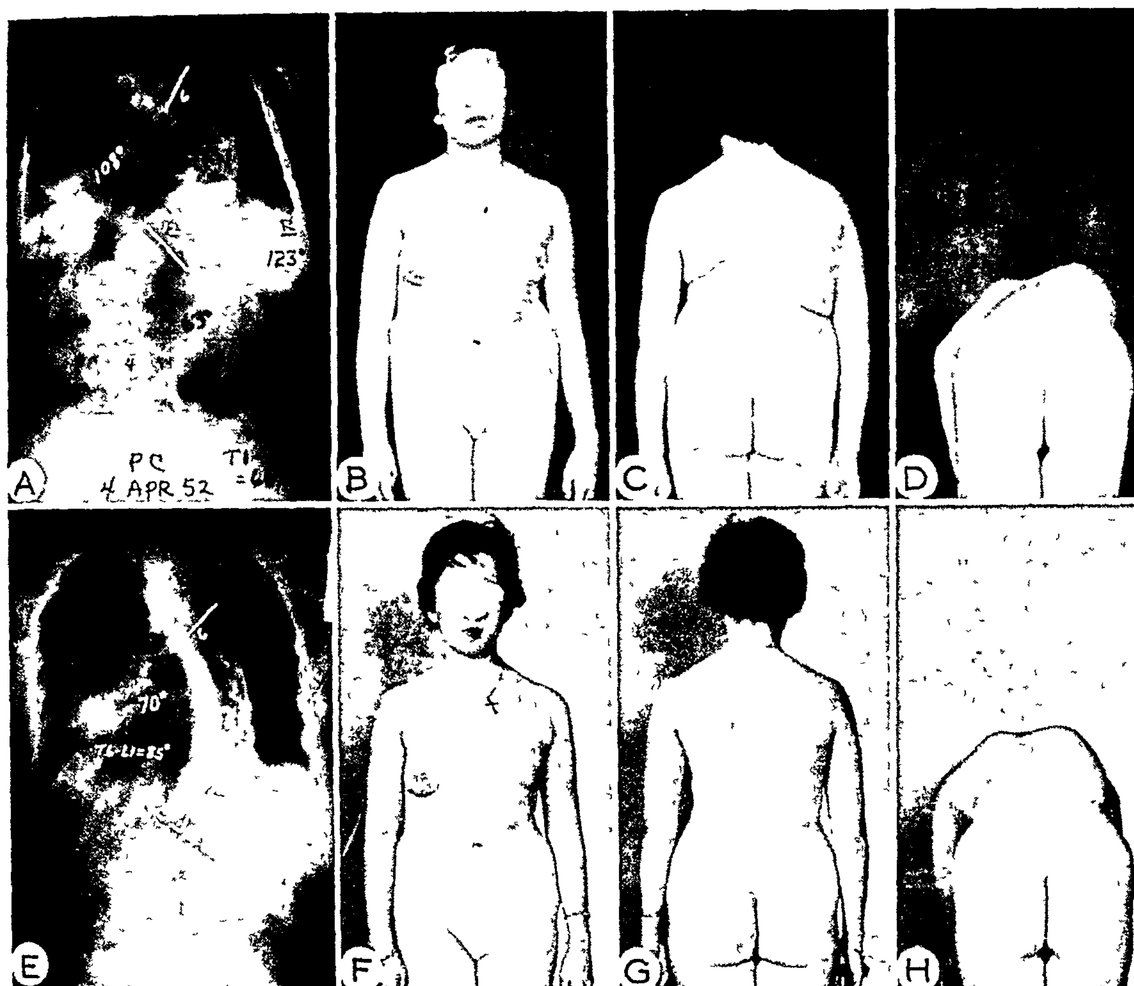


Fig 33. *Case P. Cam.* IDIOPATHIC SCOLIOSIS COMBINED THORACIC AND LUMBAR CURVE. Age at operation — twelve years and eleven months. Supplementary bone used — fresh autogenous ilium

A,B,C,D—Preoperative

E,F,G,H—Five years and eight months postoperative This case illustrates over-correction of the thoracic curve with a fusion which omitted the bottom vertebra in the primary curve As a consequence recurrence of angulation at the unfused joint in the primary curve (T11-12) and extension of the primary curve to include L1 compensates for the over-correction, with a well-balanced trunk as a final result Compare with *Case L Ric.* (Fig 35)

Case M Gol (Fig 34) presents a similar situation in which there was a rapid increase in the spinal deformity during the year prior to operation A right thoracic curve of 107 degrees was corrected to 57 degrees and a long fusion was performed including two vertebrae above and two below the primary curve. There seems to be no particular advantage in the long fusion in this type of case Measurement of all of the curves reveals 104 degree angulation to the right and 116 degrees to the left nine years postoperative, at the age of twenty-one years

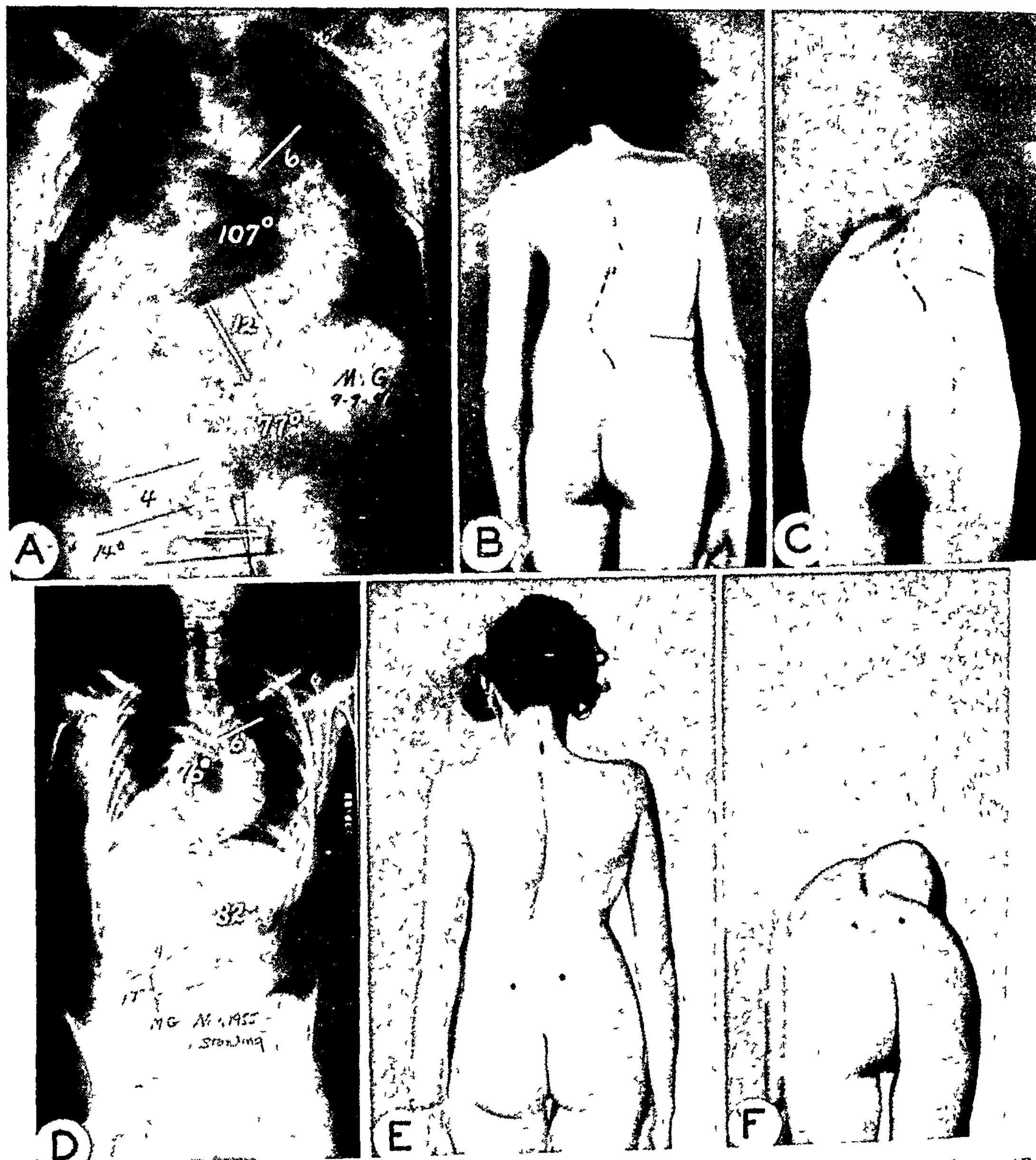


Fig 34 *Case M Gol* IDIOPATHIC SCOLIOSIS COMBINED THORACIC AND LUMBAR CURVE. Age at operation — twelve years and one month Supplementary bone used — osteoperiosteal graft

A,B,C—Preoperative

D,E,F—Nine years postoperative

A long fusion performed prior to completion of spinal growth has resulted in a satisfactory end result.

Case L Ric (Fig 35) shows the undesirable result of over-correction when the entire primary curve is fused In this patient preoperative lateral bend roentgenograms showed a fixed angulation to the left of 79 degrees. A right thoracic curve of 93 degrees was corrected to 53 degrees and at two years postoperative correction is maintained at 56 degrees As a result, there is a list of the trunk to the side opposite the corrected curve Comparing this result with the one obtained in *Case P Cam.* (Fig 33), one would surmise that if one vertebra at the top and bottom of the primary curve were excluded from the fusion, recurrence of angulation at these levels would allow restoration of good trunk balance Correction and fusion of the thoracic and lumbar curves have not been performed in this series

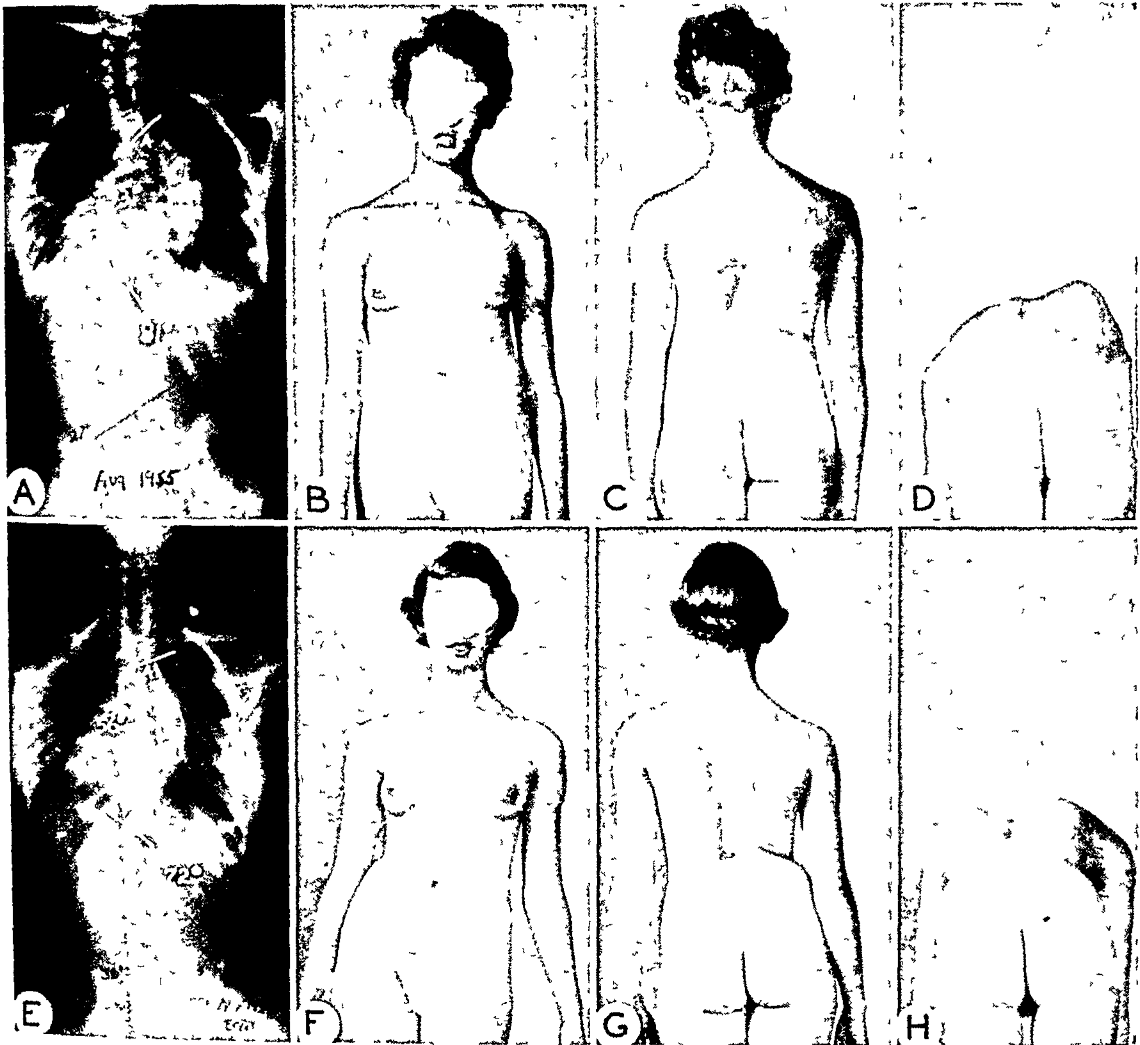


Fig 35 *Case L Ric* IDIOPATHIC SCOLIOSIS COMBINED THORACIC AND LUMBAR CURVE Age at operation — twelve years and six months Supplementary bone used — fresh autogenous ilium

A,B,C,D—Preoperative

E,F,G,H—Three years and two months postoperative A right thoracic curvature was over-corrected in relation to the fixed angulation in the left lumbar curve and the thoracic alone was fused This over-correction results in a list of the trunk to the side opposite the fused curve

PARALYTIC SCOLIOSIS

Paralytic scoliosis is treated conservatively during the period of evolution of the curve as discussed in Chapter I under "Initial Management." The goal of conservative treatment is to slow the progress of the curvature and to maintain spinal mobility. An effort is made to carry on with conservative measures to as near the time of bone maturity as possible. As in the idiopathic curvatures, surgery performed after the completion of spinal growth allows more accurate prediction of the final postoperative result.

Illustrative Case

Case G. Lin (Fig 36) is an example of the therapeutic regimen in a case of paralytic scoliosis This patient contracted paralytic poliomyelitis in the summer of 1949 at the age of eight and one-half years There was a severe degree of residual muscle paralysis in the trunk A progressive scoliotic deformity developed After an initial period in recumbency, the patient was treated with a vigorous stretching exercise routine to maintain spinal mobility, strengthening exercises for the weak muscles, and a removable bent plaster cast for trunk support during walking The progress of the curve was followed not only by the routine antero-posterior views of the spine in the standing and recumbent positions but also with lateral bend roentgenograms to determine how much fixed deformity was developing in the primary curve and also in the compensatory counter curves So long as the bend roentgenograms show maintenance of spinal mobility without great increase in the degree of fixed deformity, the conservative routine can be continued until or after the completion of spinal growth This patient was treated in this manner for six years with progression of a right thoracolumbar curve to 83 degrees. Concern was not felt for the progressive deformity because lateral bend roentgenograms showed maintenance of good mobility At the age of fifteen, surgical treatment was undertaken with the assurance that good correction could be obtained and, with a solid fusion, an excellent result anticipated

In the eighteen patients with solid fusion, loss of correction varied from 0 to 20 degrees. The loss of correction in ten patients was 10 degrees or less, and in eight patients 11 to 20 degrees. The seven of these eighteen patients in whom supplementary fresh autogenous ilium was used in the fusion lost less than 10 degrees in correction.

The per cent correction gained preoperatively in these twenty paralytic curvatures was as follows: One curvature was corrected 39 per cent; five patients were corrected between 40 and 49 per cent; one was corrected 55 per cent; four patients 60 to 69 per cent; seven patients 70 to 79 per cent; and in two patients there was 80 per cent and 85 per cent correction respectively.

The per cent loss of preoperatively gained correction in the eighteen patients with solid fusion was as follows: In the patients who had fusion with *all other type grafts,* one lost 2 per cent; three patients lost correction between 11 and 20 per cent; three patients lost 21 to 30 per cent;

three patients lost 31 to 40 per cent, and another patient 54 per cent of the correction gained.

In those patients in whom the fusion was performed with *fresh autogenous iliac bone* supplement, five patients lost 10 per cent or less and one patient each lost 18 per cent and 12 per cent of correction gained.

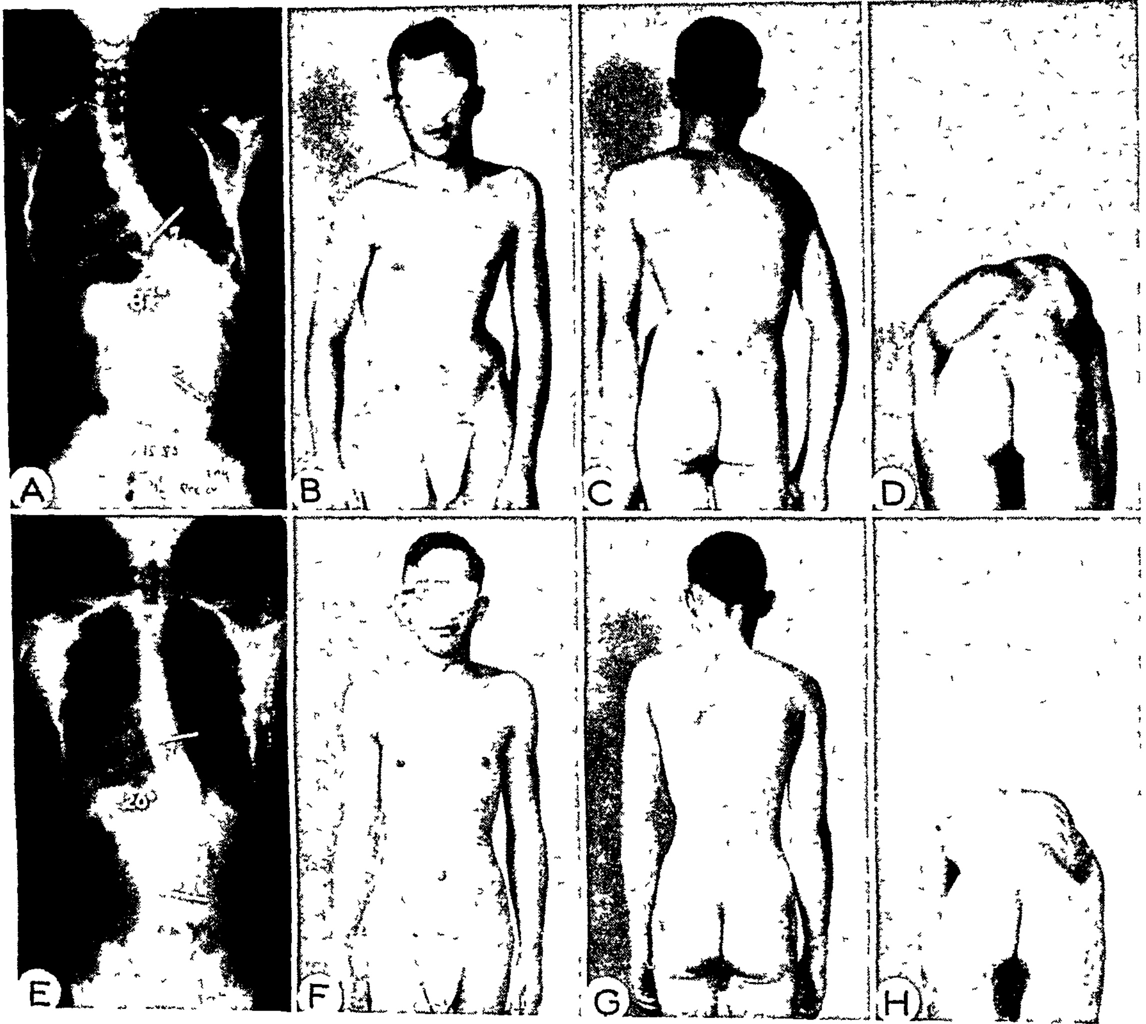


Fig 36 *Case G Lin* PARALYTIC SCOLIOSIS RIGHT THORACOLUMBAR CURVE Age at operation — fourteen years and eleven months Supplementary bone used — fresh autogenous ilium

A,B,C,D—Preoperative.

E,F,G,H—Two years and six months postoperative Primary curve plus one vertebra above was included in the fusion Excellent correction was retained in a mobile thoracolumbar curve

TABLE VI

PARALYTIC

Case	Precorrection Curve	Pre-op Corrected Curve	Extent of Fusion	Final Curve (Primary)	Follow-up (yr + mo)
E C	143°	64°	2+(T8-L4)+2	87°	9+9
N H.	120°	73°	1+(T5-12)+3	85°	17+0
G O	73°	20°	(C7-T10)+1	21°	10+3
P F.	55°	15°	(T3-11)+1	28°	9+10
R W	65°	10°	(T3-L3)+3	27°	5+6
N Mon	54°	13°	(T9-L3)+1	20°	4+4
C Cl	76°	22°	1+(C7-T8)+2	30°	9+2
B J	79°	29°	1+(T8-L3)+1	84°	6+0
L La	120°	70°	2+(T3-11)+2	85°	6+0
C Rob	77°	22°	1+(T7-L2)+1	27°	5+0
L Ba	97°	50°	(T2-10)	67°	4+9
T F	75°	30°	1+(T6-12)+1	38°	4+0
C Se	93°	48°	(T6-L2)	65°	3+0
C Rot	82°	45°	-1 (T1-12)+1	65°	3+10
C Ren	100°	32°	1+(T1-12)	45°	3+10
N Mc	63°	18°	1+(T8-L3)	16°	2+6
G Lin	83°	15°	1+(T9-L3)	20°	2+6
D Kr	87°	23°	1+(T5-11)	31°	2+6
B Mu	95°	28°	2+(T9-L3)	32°	2+6
C K	122°	70°	(T10-L3)	73°	4+0

*Primary curve is in parenthesis, numbers outside parenthesis indicate additional vertebrae, proximal (left) and distal (right), included in the fusion

†OP = osteoperiosteal graft supplement BB = banked homogenous bone supplement AI = fresh autogenous ilium supplement BAI = banked autogenous ilium supplement

TABLE V

SCOLIOSIS

Per cent Pre-op Correction	*Per cent Loss of Correction*	*Age at Operation (yr + mo)*	*Months Recumbent*	*Type of Graft†*	*Status of Fusion*
55	**29**	16+0	*9*	OP	pseud repai
39	**25**	19+0	*6*	OP	solid
73	**2**	13+2	*5*	OP	solid
73	**32**	10+9	*6½*	OP	solid
85	**31**	18+6	*9*	BB	solid
76	**17**	14+11	*6½*	OP+BB	solid
71	**15**	15+0	*6*	BB	solid
63	**100**	12+8	*8*	BB	pseud
42	**30**	13+8	*10*	OP+BB	solid
71	**9**	13+0	*7*	AI+BB	solid
48	**36**	10+6	*9*	BAI	solid
60	**18**	14+5	*9*	AI	solid
48	**38**	23+0	*9*	BAI	solid
45	**54**	17+0	*9*	BAI	solid
68	**19**	13+8	*10*	BAI	solid
71	**0**	15+5	*7*	AI	solid
82	**7**	14+11	*9*	AI	solid
73	**12**	16+0	*6*	AI	solid
70	**6**	11+5	*6½*	AI	solid
43	**6**	16+0	*8½*	AI+BB	solid

Illustrative Cases — Paralytic Scoliosis

Case B J (Fig 37) A postoperative wound infection occurred following the first stage of a two-stage fusion which was performed with banked bone supplement A pseudarthrosis developed with loss of all correction A postoperative wound infection occurred in *Case C K* (Fig 44) who had a one-stage fusion using fresh autogenous ilium as supplement There was no delay in the development of a solid massive fusion in this case and correction was maintained

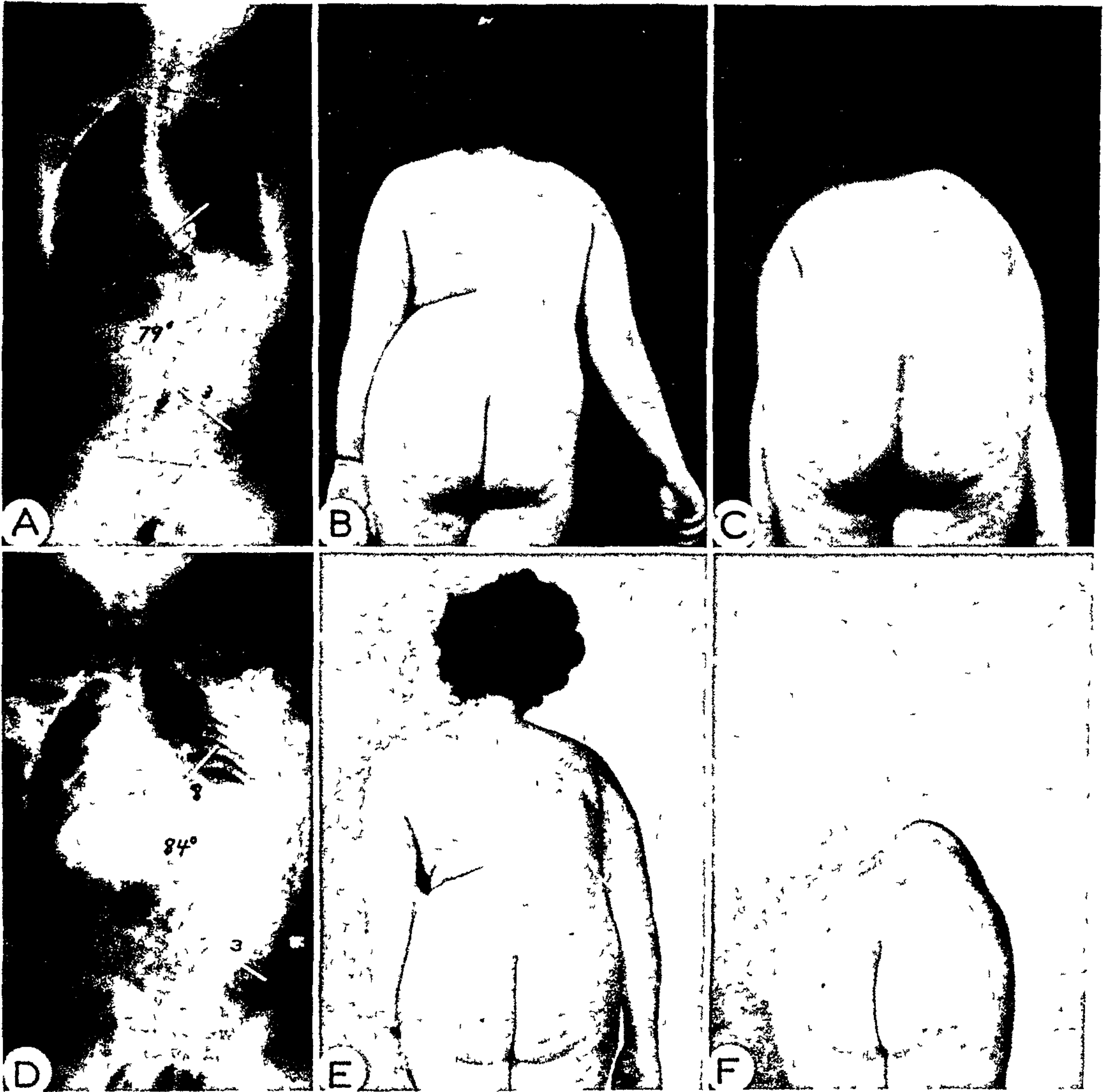


Fig 37 *Case B J* PARALYTIC SCOLIOSIS THORACOLUMBAR CURVE Age at operation — twelve years and eleven months Supplementary bone used — osteoperiosteal graft

A,B,C—Preoperative

D,E,F—Six years postoperative Loss of all correction gained preoperatively due to the development of a pseudarthrosis

The fusion in *Case C Cl* (Fig 38) a cervicothoracic curve, included the primary curve plus one vertebra above and two below using banked bone as graft supplement In *Case G O* (Fig 39), a high thoracic curve, the fusion included one vertebra below the primary curve and was done with osteoperiosteal graft supplement.

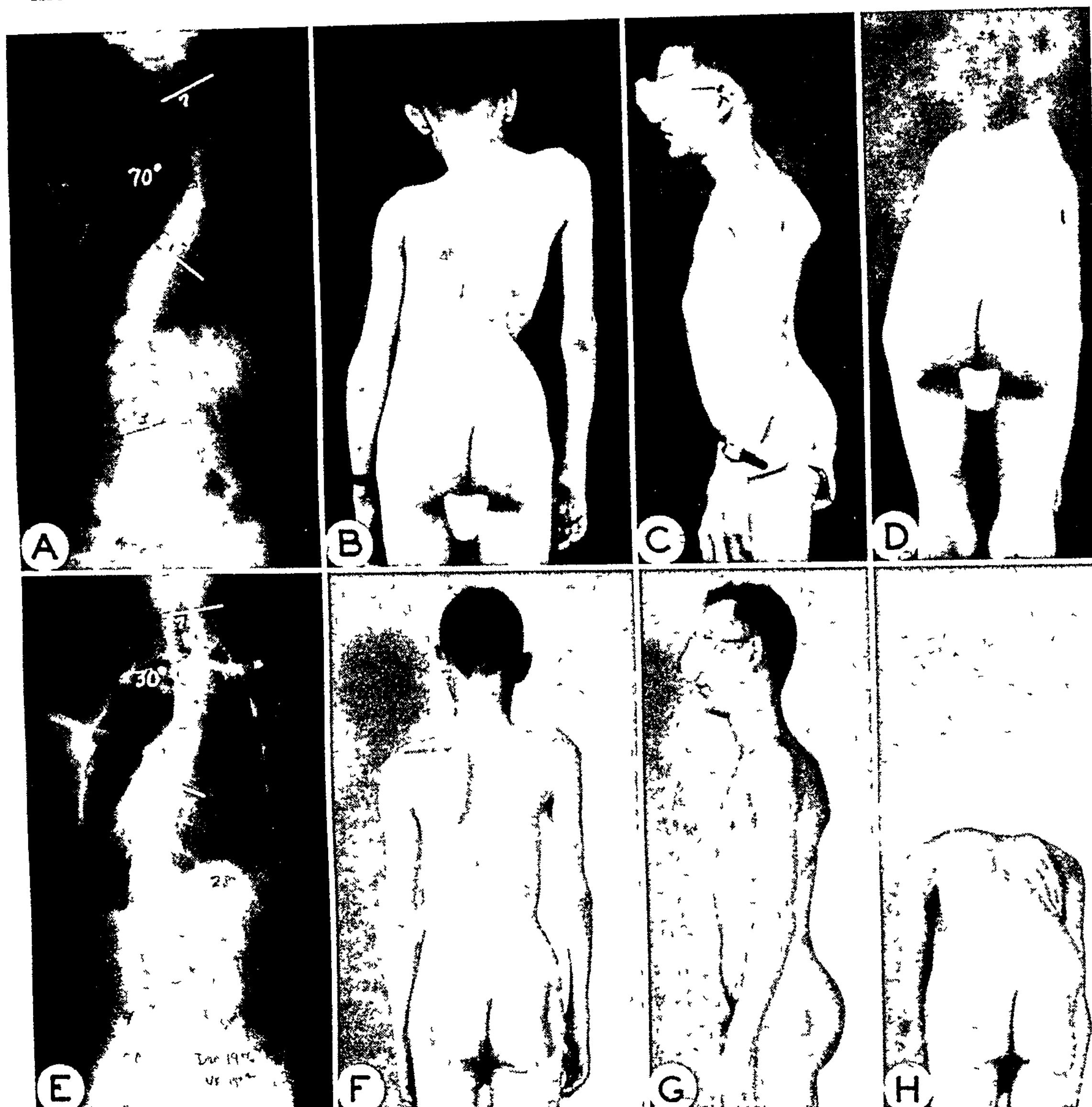


Fig 38 *Case C Cl* PARALYTIC SCOLIOSIS CERVICOTHORACIC CURVE Age at operation — fifteen years Supplementary bones used — banked bone chips
A,B,C,D—Preoperative.
E,F,G,H—Nine years and two months postoperative The fusion, performed in two stages, included the primary curve plus one vertebra above and two below

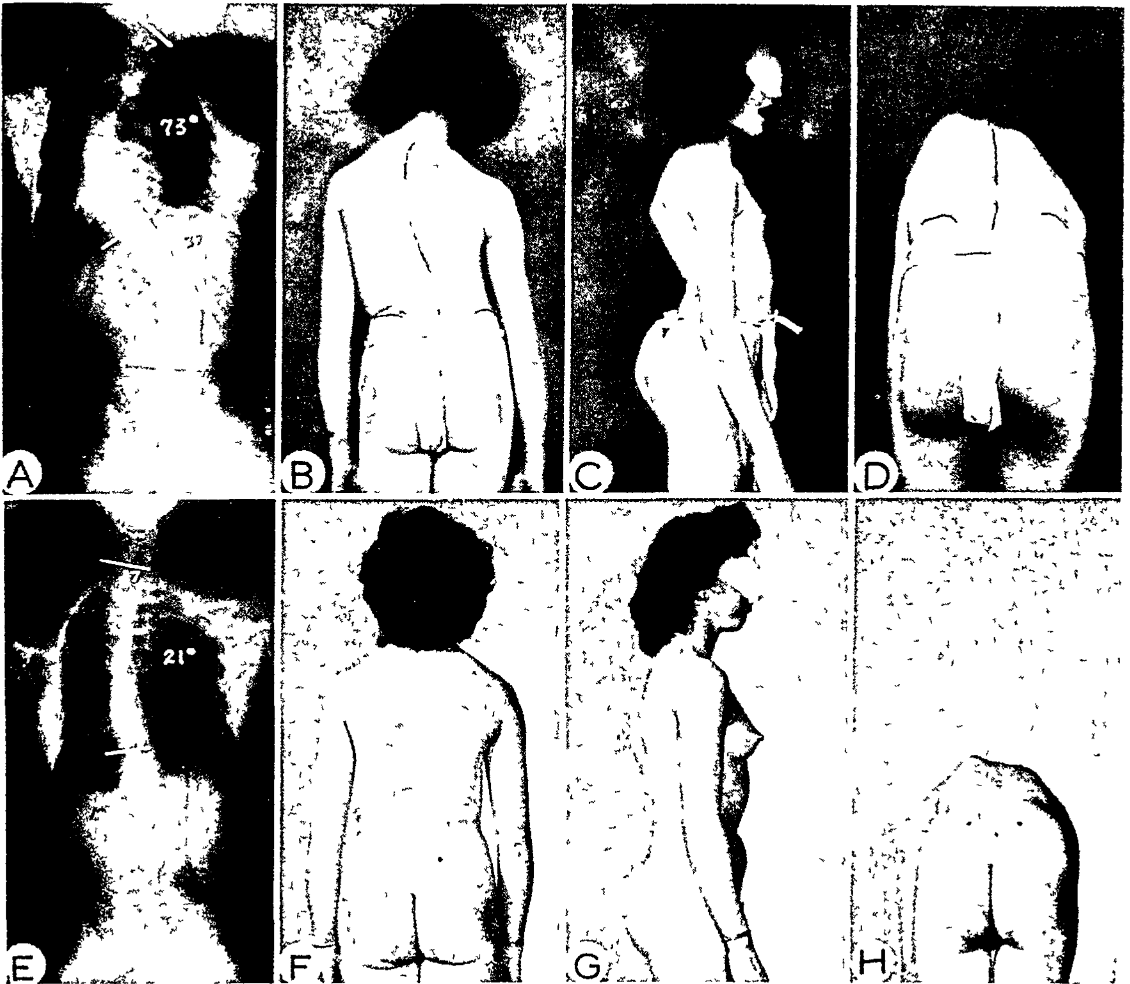


Fig 39 *Case G O* Paralytic Scoliosis. High Thoracic Curve Age at operation — twelve years and two months Supplementary bone used — osteoperiosteal graft

A,B,C,D—Preoperative

E,F,G,H—Six years and eight months postoperative

High oblique placement of the anterior and posterior hinges in the turnbuckle cast allows correction of a high thoracic curve Last examination at ten years and three months postoperative shows no change (C7—T10 = 18°)

Case N H (Fig 40) A severe rigid thoracic curve with razor-back rotational deformity was complicated by progessively increasing root pain Surgical treatment had been recommended at an earlier age but was refused by the parents. A long fusion between parallel lines was performed in two stages using supplementary osteoperiosteal grafts Good body balance and relief of pain was accomplished Correction of the rotational prominence cannot be expected in this type of deformity Resection of the prominent angulated ribs for cosmetic improvement has not been recommended



Fig. 40. *Case N. H* PARALYTIC SCOLIOSIS THORACIC CURVE Age at operation — nineteen years Supplementary bone used — osteoperiosteal graft

A,B,C—Preoperative

D,E,F—Seventeen years postoperative at the age of thirty-six years

The patient had radicular pain, preoperatively Satisfactory correction of this severe deformity was obtained and pain was relieved

Case L. LaM (Fig 41) The patient was lost to follow-up two years after onset of poliomyelitis and returned four years later with a severe rigid thoracic curve badly decompensated A two-stage fusion was performed which included the primary curve plus two vertebrae above and two below and was supplemented with an osteoperiosteal graft and banked bone chips At six years after operation, there is good body balance with satisfactory correction maintained

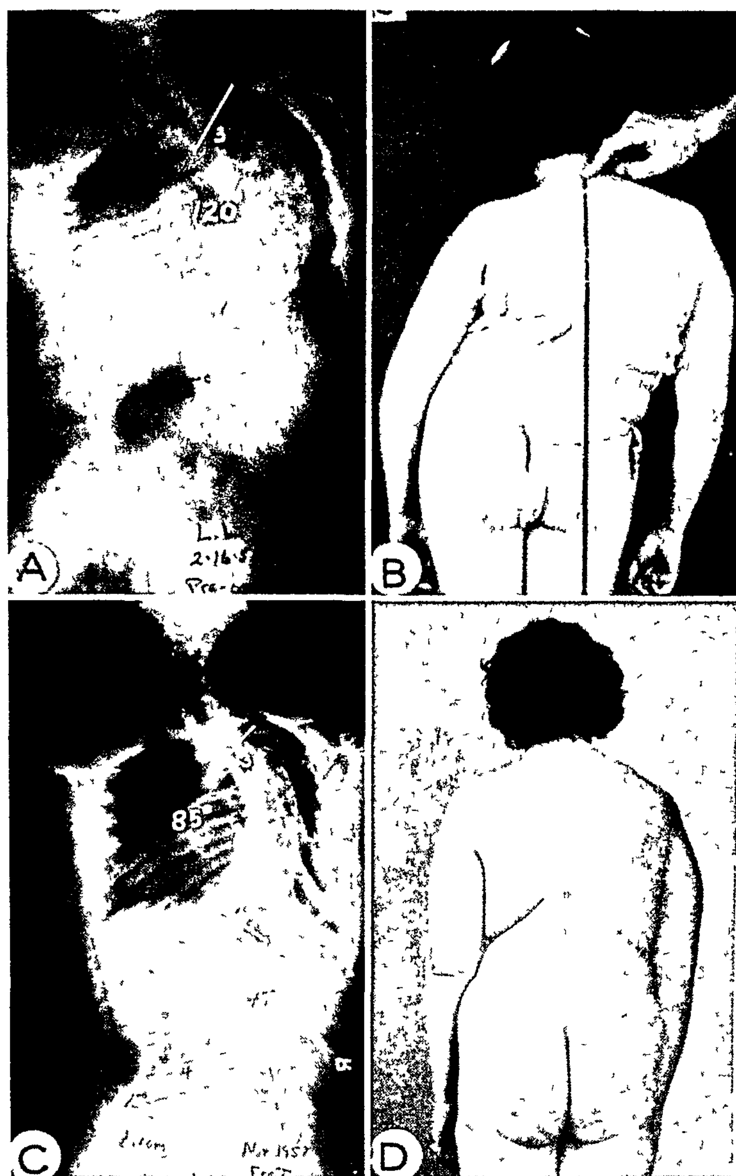


Fig 41 *Case L LaM* Paralytic Scoliosis Severe Thoracic Curve Age at operation — thirteen years and eight months Supplementary bone used — banked bone chips and osteoperiosteal graft.

A,B—Preoperative

C,D—Six years postoperative The fusion included the primary curve plus two vertebrae above and two below

Case C. Ren (Fig 42). An unstable thoracic curve was associated with a marked degree of residual trunk paralysis and showed severe decompensation The primary curve alone was fused, using supplementary banked autogenous ilium Bone was removed first from both ilia and placed in the bone bank Two weeks later the turnbuckle plaster cast was applied, the curvature corrected, and the banked autogenous ilium was used as supplementary grafts in the fusion This was done because more bone than is obtainable from one ilium was required and rather than doing the spine fusion in two stages, using one ilium for each stage, the spine fusion itself was performed in one stage using the previously removed iliac bone which had been banked This patient continues to wear a removable celluloid jacket because of the extensive trunk paralysis Since he does not mind wearing the jacket, extension of the fusion to stabilize the lumbar spine has not been considered or recommended



Fig 42 *Case C Ren* Paralytic Scoliosis Long Left Thoracic Curve Age at operation — thirteen years and eight months Supplementary bone used — banked autogenous ilium.

A,B,C—Preoperative.

D,E,F—Three years and ten months postoperative This patient had very extensive paralysis of the trunk including abdominal and spinal extensor musculature as well as severe residual involvement in the lower extremities He uses two crutches for distance walking and wears a removable celluloid jacket (*G*).

Case B. Mu (Fig. 43). Fusion was done at the age of eleven years and five months and included the primary curve plus two vertebrae above. The primary left thoracolumbar curve was over-corrected in relation to the total fixed angulation in the counter curves Postoperatively, further increase in the right thoracic curve has occurred with gross decompensation of the trunk At this age with structural thoracic and thoracolumbar curves, correction and fusion of both curves in balance is indicated [17] This patient could have been treated for a longer period conservatively with stretching exercises to maintain mobility and with support of the trunk in a Milwaukee brace The upper thoracic curve has now been corrected in a turnbuckle cast, the body alignment balanced and fusion extended to include the first thoracic vertebra Compare this patient with *Case C. K* (Fig. 44) showing a similar curve which was operated on after completion of spinal growth In the latter patient progressively increasing backache had developed before treatment and was relieved by operation

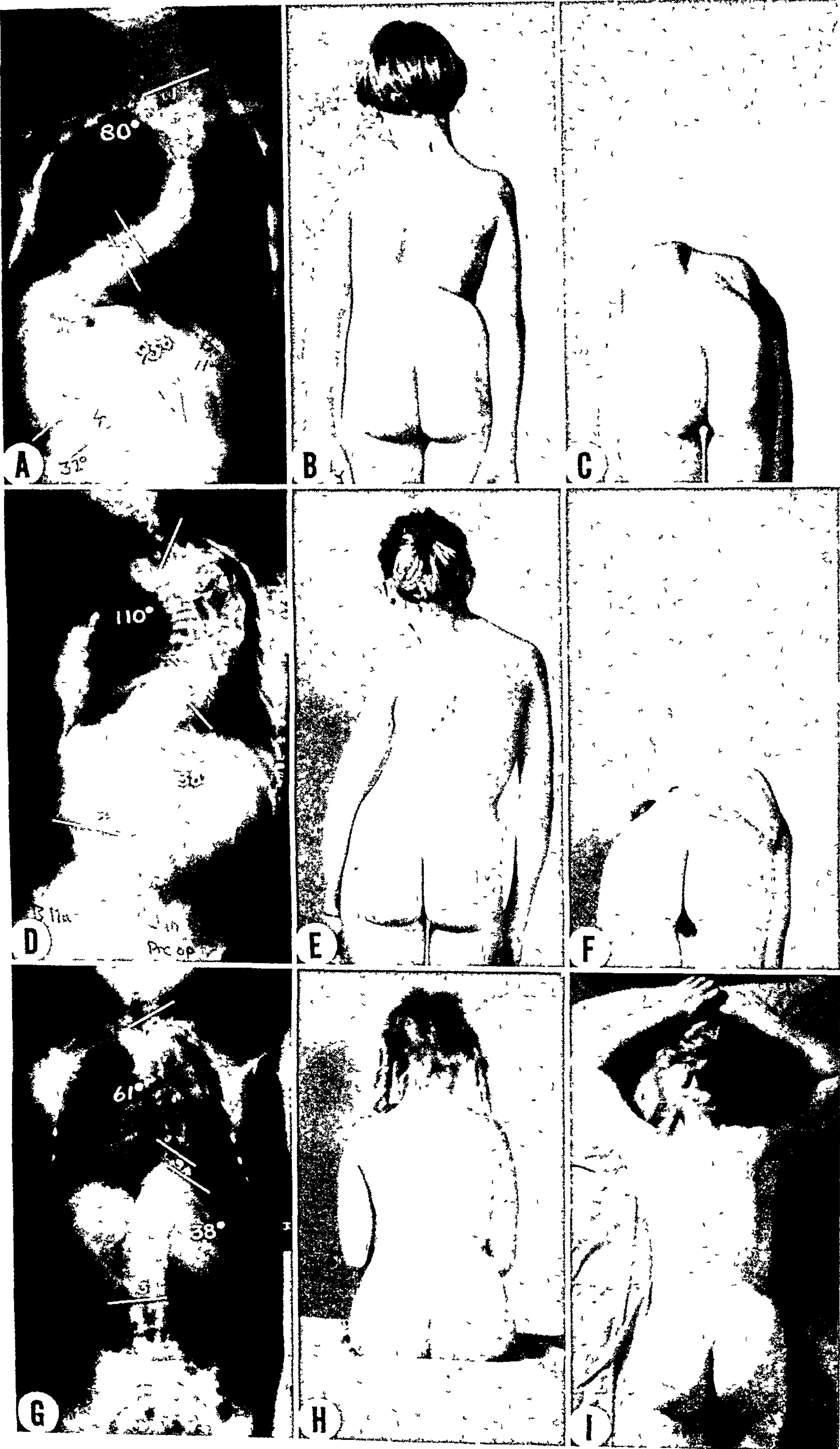
(Fig 44 follows on page 88)

Fig 43 (Facing page) *Case B Mu* PARALYTIC SCOLIOSIS THORACOLUMBAR CURVE Age at first operation — eleven years and five months, second operation — fourteen years Supplementary bone used — fresh autogenous ilium

A,B,C—Preoperative

D,E,F—Two years and seven months postoperative The left thoracolumbar curve was initially over-corrected in relation to the fixed angulation in the opposite direction Fusion was performed at an early age before completion of spinal growth An increase in the right thoracic curvature has occurred since operation

G,H,I—Six months after turnbuckle correction and fusion of the right thoracic curve Good balance has been achieved There is a massive, solid fusion


80°
A
B
C
110°
D
E
F
61°
38°
G
H
I

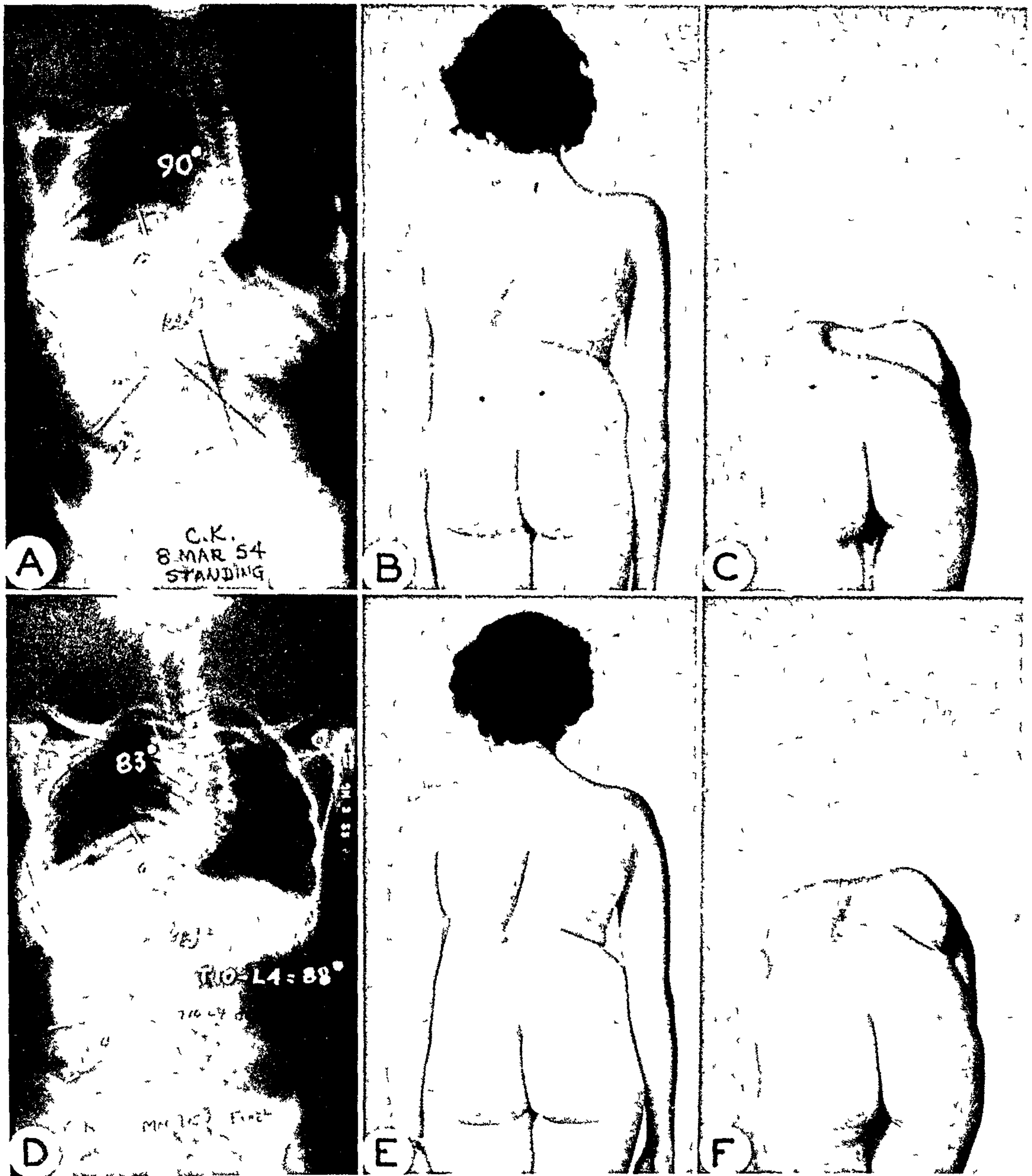


Fig 44 *Case C K* PARALYTIC SCOLIOSIS THORACOLUMBAR CURVE Age at operation — sixteen years Supplementary bone used — fresh autogenous ilium and banked bone chips

A,B,C—Preoperative

D,E,F—Three years postoperative This girl was unable to sit through her classes at school because of increasing fatigue and backache. Symptomatic relief followed surgical treatment. A postoperative wound infection did not interfere with the formation of a massive solid fusion Last examination at four years postoperative shows no change (T10-L3=73°).

Case L Ba (Fig. 45) A rapidly progressive paralytic curvature in infancy was treated initially elsewhere, by correction in a turnbuckle plaster cast and a short spinal fusion (T4-8) at three years of age The second spinal fusion was done at the age of ten years and nine months because of a steadily progressing rigid high thoracic curvature, with a severe kyphotic deformity The fusion at this time was extended above and below the initial graft to include all of the primary curve This case is a good example of the effectiveness of a short fusion at a very early age with lessening of the progress of the deformity at the apex of the curve, thus allowing postponement of the final definitive treatment and extension of the fusion to include all of the primary curve until the patient was older.

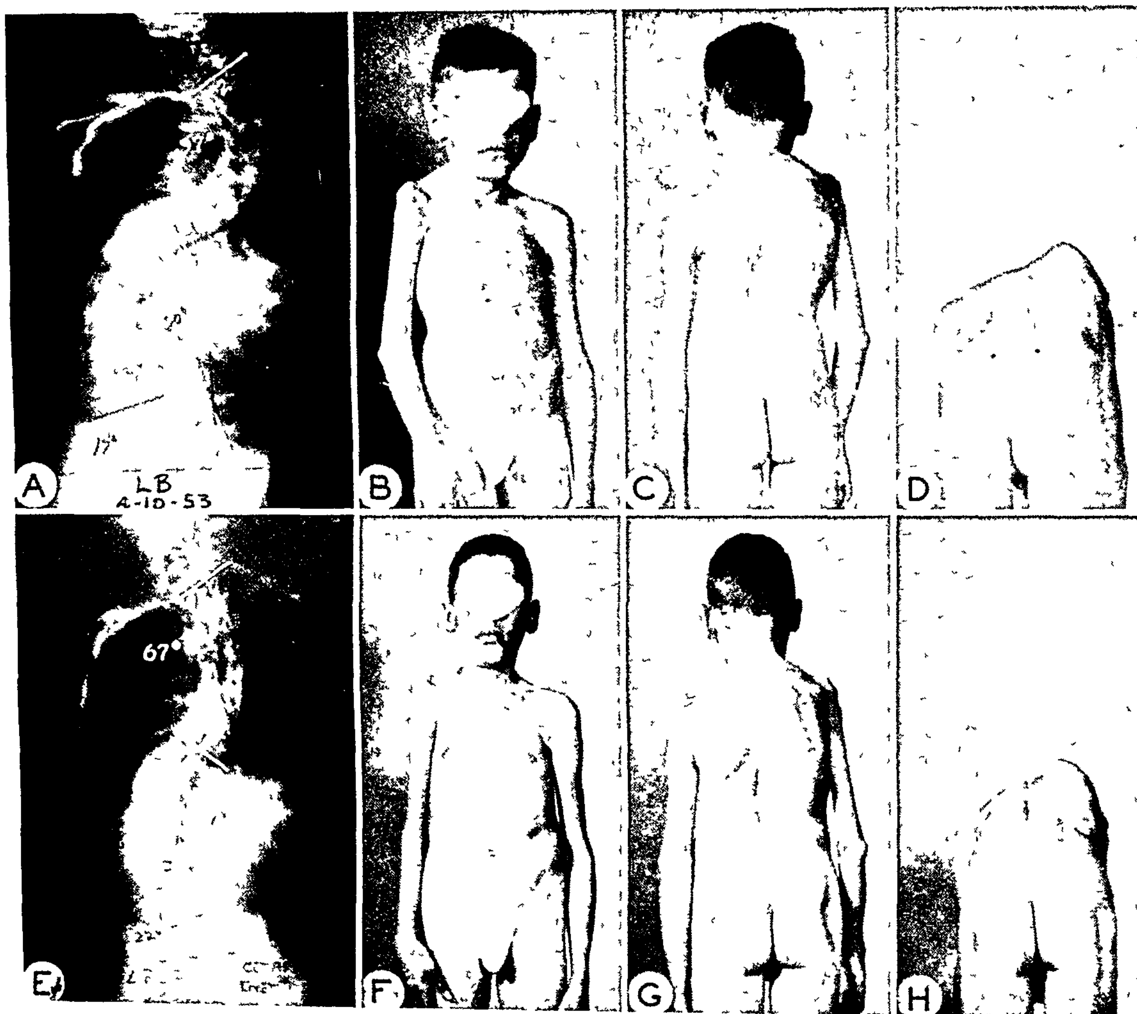


Fig 45 *Case L Ba* PARALYTIC SCOLIOSIS: THORACIC CURVE Age at second operation — ten years and nine months Supplementary bone used — banked autogenous ilium

A,B,C,D—April 1953, prior to second correction of the curvature and spinal fusion

E,F,G,H—October 1957, four years and four months after the second fusion at the age of fifteen years and one month This case demonstrates the effectiveness of a short fusion (a portion of the primary curve) at a very early age in lessening the progress of a scoliotic deformity at the apex of the curvature and permitting postponement of the final definitive surgical treatment to an older age (Last examination four years and nine months post-operative, same correction retained)

Case R W (Fig 46). This patient represents a special problem in which the scoliosis was associated with a significant degree of fixed pelvic obliquity. There was a severe degree of residual paralysis in the trunk and all four extremities. The spinal fusion was performed in three stages using supplementary banked bone grafts. The left thoracolumbar curve was first corrected and the spine fused from the third thoracic to the third lumbar vertebra in two stages Four months later the hinges were placed to allow turnbuckle wedging for correction of the right lumbosacral curve This was accomplished and the pelvis lined up with the fused thoracic spine The fusion was then extended from the third lumbar vertebra to include the sacrum

Case E. C (Fig 47) presented a similar problem — a severe thoracolumbar curve associated with a marked degree of fixed pelvic obliquity The fusion, using supplementary osteoperiosteal grafts, was extended to include the sacrum with advantage, although complete correction of the pelvic obliquity was not obtained A pseudarthrosis was repaired at the lumbosacral level one year postoperatively, and another pseudarthrosis occurring at the upper lumbar level healed spontaneously Satisfactory correction was retained.

Fig. 46 *Case R W*. PARALYTIC SCOLIOSIS LONG THORACOLUMBAR CURVE WITH FIXED PELVIC OBLIQUITY. Age at operation — eighteen years and six months Supplementary bone used — banked bone chips

A.B—Preoperative.

C,D—One year postoperative.

E —Five years and six months postoperative.

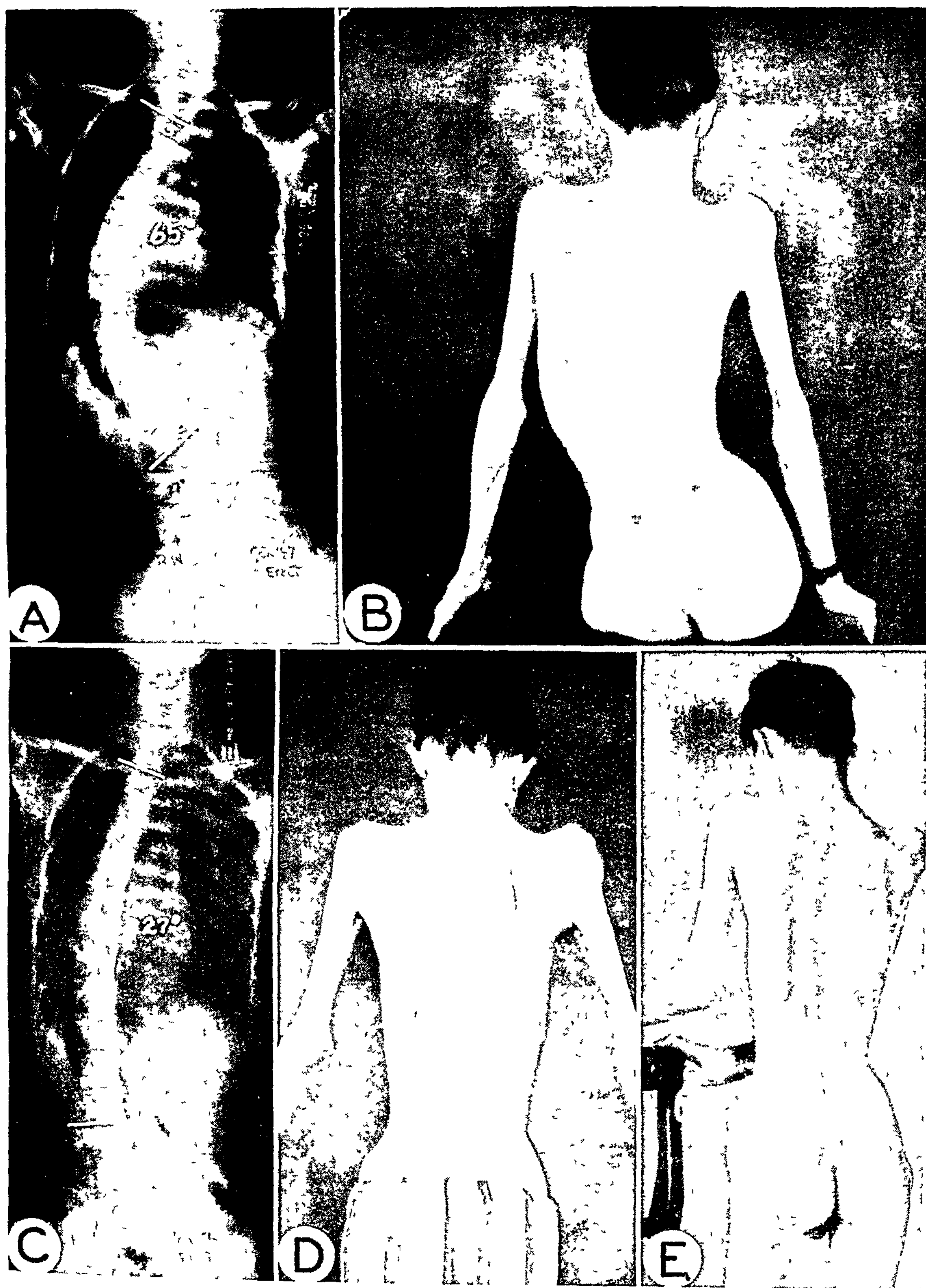


Fig 46 *(Legend on facing page)*



Fig 47. *Case E C* Paralytic Scoliosis Left Thoracolumbar Curve with Fixed Pelvic Obliquity Age at operation — sixteen years Supplementary bone used — osteoperiosteal grafts

A,B,C—Preoperative.

D E,F—Nine years and six months postoperative The fusion extended from the sixth thoracic vertebra to the sacrum and was performed in two stages A pseudarthrosis at the lumbosacral level was repaired one year after the fusion operation and a second pseudarthrosis developing at the joint between the twelfth thoracic and first lumbar vertebrae healed spontaneously A very satisfactory degree of correction has been retained

(From *Medical Clinics of North America*[9] Courtesy W B. Saunders Co , Philadelphia, Pennsylvania)

CHAPTER VIII

Summary

In summarizing the salient points covered in this monograph it is to be emphasized that all cases were treated by the author by one method.

1. Preoperative analysis of the scoliotic deformitly including evaluation of the degree of fixed angulation in the compensatory counter curves permits determination of the allowable correction.

2. As a basic principle, the angular deformity of the primary curve should not be corrected beyond the sum of the angles of the compensatory counter curves.

3. All correction is obtained preoperatively in a turnbuckle plaster cast.

4. Details in the application of the turnbuckle plaster cast are important. The molded head-piece, the method of placement of the hinges, and the inclusion of both thighs exert a distracting as well as a lateral bending force as the turnbuckle is extended during correction of the curvature.

5. The distracting force, exerted throughout the period of correction and maintained during the immediate six months' postoperative period in the turnbuckle plaster cast, assures uniform results.

6. By obtaining the desired correction preoperatively and maintaining that correction postoperatively during the period of maturation of the fusion, superior results are achieved.

7. After the desired correction is accomplished, a spine marker roentgenogram made to allow positive identification of a spinous process at or near the distal end of the proposed fusion area insures proper placement of the fusion.

8. Postoperative immobilization in these cases, including eight months in recumbency (six months in Risser cast and two months in bent cast) and a total of ten months in plaster casts, had resulted in fusions of sufficient strength to hold correction after the first postoperative year.

9. Seventy-five per cent of the curvatures measured 70 degrees or more.

10. There was no problem in obtaining the desired degree of correction with the turnbuckle plaster cast. Forty-five per cent of the cases

were corrected 70 per cent or more. The remainder were corrected between 39 and 69 per cent.

11. Of twenty-five consecutively treated patients in whom supplementary fresh autogenous ilium was used in the fusion, fourteen patients lost 10 per cent or less in preoperatively gained correction, eight patients lost between 11 and 21 per cent, one patient lost 25 per cent and another lost 55 per cent. One pseudarthrosis occurred in this group of cases with 26 per cent loss of correction.

12. In the same twenty-five patients in whom supplementary fresh autogenous ilium was used, there was no loss greater than 6 degrees or 11 per cent of the correction gained preoperatively after the first postoperative year. There were no graft fractures or so-called delayed pseudarthroses observed after the first postoperative year.

13. A carefully performed spinal fusion with use of a large amount of supplementary fresh autogenous iliac bone results in prompt formation of a massive solid fusion which is fully matured at one year.

14. The surgical treatment for scoliosis is performed primarily because of the malformation of the trunk. It is often thought of as a cosmetic procedure. One must not forget that satisfactory correction of the deformity often has a profound influence psychologically on the individual's personality and outlook on life, and improved function is a recognized advantage.

15. This experience has provided the answer to some questions but many others remain unanswered, to be clarified, it is hoped, by future experience and investigations.

ADDENDUM

As of December 1958, a total of seventy-five patients has been treated by means of turnbuckle plaster cast, correction, and spine fusion. In Chapter VI the results in fifty-one patients with idiopathic and paralytic scoliosis are analyzed. Ten more patients have now been followed between one and two years after operation. There are no pseudarthroses in these ten additional patients. In a total of thirty-five consecutive patients in whom fresh autogenous iliac bone has been used to supplement the fusion, there is one pseudarthrosis (an incidence of 3 per cent). There are no pseudarthroses in the last twenty-seven consecutive patients treated by means of this technique. The per cent loss of preoperatively gained correction in the ten patients with more recent follow-up is as follows: eight patients lost 10 per cent or less, one patient lost 12 per cent, and another, 16 per cent.

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APPENDIX

Anesthesia in Scoliosis

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ANESTHETIC PROBLEMS

The problems which confront the anesthesiologist can be conveniently considered in three groups: (1) those presented by the patient; (2) those resulting from the site, magnitude, and technique of the operation; (3) those associated with the turnbuckle cast.

The Patient

Virtually all the patients were in late childhood or adolescence; hence many of them were frightened and tense at the prospect of the operation. Anxiety during the weeks preceding surgery was allayed by frequent reassurance and support by the nursing and medical staffs, and fairly heavy preanesthetic sedation was employed on the morning of operation.

The respiratory reserve of a scoliotic patient may be below normal for two reasons. First, the ability to ventilate one or both lungs may be impaired by the deformity itself; second, a postpoliomyelitis patient may have residual weakness of the muscles of respiration (two of the poliomyelitis patients in this series had required tank respirator treatment during the acute phase of the disease). Although impaired breathing powers could predispose to oxygen lack and carbon dioxide excess under anesthesia, the anesthetist can readily correct such faults *during* surgery while the patient is under his direct care.

The greatest respiratory risk is in the forty-eight hours immediately *after* surgery. During this time the ability to clear the tracheobronchial tree by coughing may be lessened by immobility, by pain, and because of depression of the cough reflex by narcotic drugs used to relieve pain.

The assessment of each patient from the point of view of the risk of anesthesia and surgery was made principally upon a careful consideration of history and clinical examination. In many cases simple respiratory measurements such as resting tidal and minute volumes and vital capacity were made, but it has not seemed to us to be necessary to perform elaborate pulmonary function tests. During this work no

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patient has been considered to be an unacceptable risk from the standpoint of anesthesia or respiratory function.

Site, Magnitude, and Technique of the Operation

Because operation is done in the prone position, intubation of the trachea is essential to maintain safe control of the airway.

Blood loss is often moderately heavy, and citrated whole blood has been transfused in amounts varying from 1,000 cc. to 2,000 cc. at each operation. Efforts to minimize bleeding and to shorten the operation have included infiltration of the operative sites with 1:200,000 solution of epinephrine and electrocoagulation of small bleeding points. In recent years an average operating time of slightly over two hours has been achieved. The electrocautery presents the anesthetist with a potential explosion hazard and the injection of epinephrine dictates the omission of trichlorethylene.

The Turnbuckle Cast

Although sufficient room is left to enable the mouth to open, no lateral movement and little or no flexion of the cervical spine is possible. Tracheal intubation presented moderate or severe difficulty in approximately one-fourth of the cases.

The commonest cause of trouble was inability to expose the larynx adequately; in some cases it was impossible to see farther than the epiglottis. Fixation of the head and neck precluded maneuvers which the anesthesiologist can ordinarily employ in difficult laryngoscopies, such as flexion or extension of the cervical portion of the spinal column or of the atlanto-occipital joint.

Denton and O'Donoghue, reporting their experience in a series of patients operated upon by James, stated that in the patients in whom limited extension of the neck was expected to hinder intubation, the back of the cast was made temporarily removable. James considered it unnecessary to include the head in the jacket, but in our experience it has been found that for the effective maintenance of correction of the curvature, inclusion of the head in the cast is essential. We have, therefore, worked with a nonremovable headpiece, in all cases except one. The patient in question developed acute upper gastrointestinal bleeding nine days after spinal fusion and was brought to surgery for emergency laparotomy. It was considered to be too dangerous to induce anesthesia in the usual way for fear that vomiting of blood and aspiration into the lungs would occur. Consequently, the head and chin piece were trimmed and the trachea intubated with the child awake after the throat and larynx had been sprayed with 0.5 per cent tetracaine. At the end of the operation (subtotal gastrectomy) an elective

tracheotomy was performed to facilitate control of tracheobronchial secretions.

In some patients the mouth could be opened barely enough to introduce the laryngoscope. Whereas before operation such patients usually appeared to be able to open the mouth fairly widely, when anesthetized they sank into their plaster casts like turtles into their shells.

While cardiac arrest from hypoxia or anesthetic depression is unlikely to occur in patients in this age group, it is always a possibility during major anesthetic and surgical procedures. Also, repeated attempts at intubation will increase the likelihood of postoperative respiratory obstruction from edema of the larynx.

In one patient a difficult intubation was followed by the development of laryngeal obstruction about one hour after termination of anesthesia. Cyanosis occurred but was relieved by rapid blind intubation of the trachea through the nose. An hour later, when the patient had fully awakened, the tube was removed, but obstruction recurred and tracheotomy was performed. This produced complete relief and twenty-four hours later the tracheotomy tube could be occluded without causing distress. On the ninth postoperative day it was removed completely, and the patient recovered without sequelae.

Consideration is therefore given to such possibilities in the construction of the plaster jacket. A window is cut in the front of the cast to allow exposure of the precordium and trachea if necessary.

Preanesthetic medication consisted of sodium pentobarbital in doses of approximately 2 mg. per kilogram of body weight together with 0.3 mg. of scopolamine hydrobromide, both given intramuscularly about one and one-half hours before operation. Respiratory depressant narcotics, such as meperidine (Demerol®) or morphine are omitted.

Anesthesia was induced with the patient in the supine position. Because of the tendency of the patient to slip down into the cast when anesthetized, the operating table was first tilted to a 15-degree head-down tilt and the fingers of the anesthesiologist were insinuated between the cast and the chin. Gentle traction on the mandible was then maintained from the start of anesthesia. Nitrous oxide-oxygen was used to produce unconsciousness, ether being gradually added to the inspired mixture.

Tracheal intubation was not attempted until moderately deep ether anesthesia was produced. On several occasions when laryngoscopy was difficult or impossible with a conventional instrument of the Guedel or Wisconsin type, use of a MacIntosh or Miller blade made intubation of the trachea possible. Sometimes substituting a well-curved endotracheal tube for one with only a slight curve converted initial failure into success. When intubation via the mouth failed, resort was had to the blind nasotracheal method. This route was even employed from choice

in some cases; it was not devoid of complications, however, because troublesome nasal bleeding occasionally occurred.

After tracheal intubation, the use of ether was stopped, and anesthesia was maintained with nitrous oxide-oxygen supplemented by small intravenous doses of meperidine or Nisentil®. The average total dose of meperidine was 70 mg.; when Nisentil® was used the mean total dose was 22 mg. In the early cases ether was used throughout, but it has been omitted as a maintaining agent since electrocautery has been employed. Later in the series, trichlorethylene was used to supplement the nitrous oxide-oxygen, but this denied the surgeon the advantage of using local infiltration of epinephrine[1] and has now been discontinued.

Since intubation of the trachea was not infrequently hindered and because of the possibility of producing bleeding in the airway, drugs producing apnea, such as the muscle relaxants, were deliberately avoided. Thiopental was used for induction in some cases but eventually abandoned because its respiratory depressant action retarded the achievement of an adequate depth of inhalation anesthesia. The possibility of laryngospasm coupled with inability to intubate the trachea was a further consideration influencing the decision to avoid this drug.

When anesthesia was established and stable, the patient was turned to the prone position. At this time a broad strip of adhesive tape, padded with gauze, was placed transversely across the forehead and onto the headpiece to prevent undue pressure of the cast on the chin. Careful attention was also paid to the position of the upper limbs to avoid excessive pressure or stretching. Two patients in the series had numbness and weakness of the left hand and arm immediately after operation, but prompt, complete recovery followed relief of the pressure. One arm could usually be conveniently placed on the operating table parallel to the trunk while the other was supported in a position accessible to the anesthesiologist. A reliable intravenous infusion was started before or early in the operation.

After operation the patient was cared for in a semiprone position, and the tracheal tube was left in place until consciousness had returned.

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Index

